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CLINICAL MANUALS

FOR

PRACTITIONERS AND STUDENTS OF MEDICINE.

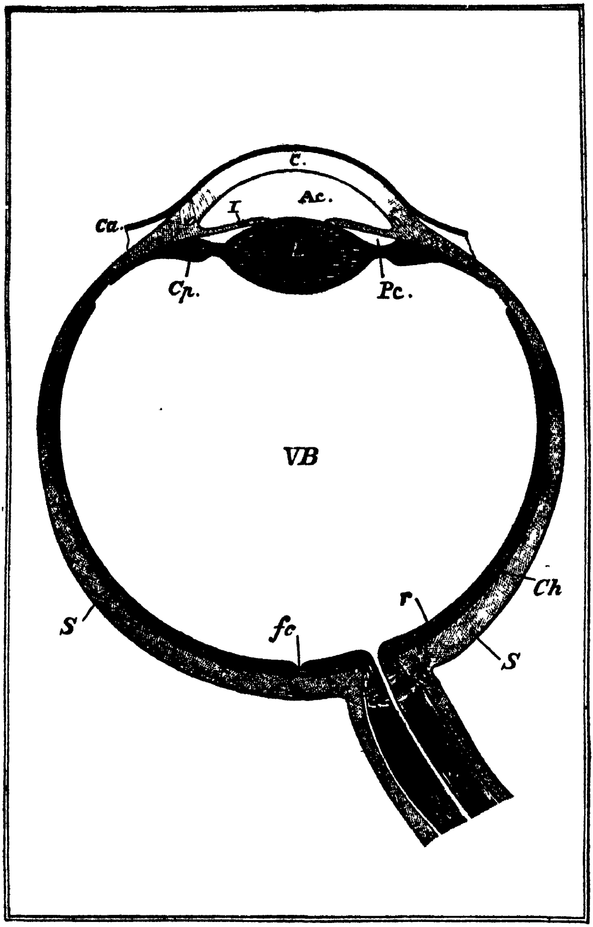

DIAGRAM OF A HORIZONTAL SECTION OF THE LEFT EYE (*Magnified about three diameters*).

Ca, Conjunctiva; C, cornea; I, iris; *Ac*, anterior chamber; SS, sclerotic; *Ch*, choroid; , retina; *l*, lens; *Cp*, ciliary process; *Pc*, canal of Petit; *fc*, fovea centralis; VB, vitreous body.

OPHTHALMIC SURGERY.

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PREFACE.

We have endeavoured, in the following pages, to place before the profession a concise account, as complete as the space at our disposal would permit, of the present state of Ophthalmic Surgery. The limitation is not an unimportant one, insomuch that we have occasionally given references to authorities from whom more detailed information on particular points may be obtained.

We have attached our initials to the chapters which we have respectively written, with the view of assuming for them an individual responsibility; but we have each of us read over the whole of the proofs, and must be taken to be in general agreement with regard to all portions of the volume.

R. B. C
W. A. F.

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OPHTHALMIC SURGERY.

CHAPTER I.

ANATOMY AND PHYSIOLOGY.

THE human eyeball, or globe of the eye, is a nearly spherical organ, composed of coats or tunics inclosing transparent substances or fluids which are collectively called the internal refracting media, and which have the function of forming inverted images of visible outward objects. The external coat is formed of two different structures; the posterior, larger, and opaque portion being known as the sclera, while the anterior, smaller, and transparent portion is the cornea. Within this external coat is a vascular membrane, the choroid, with which an anterior perforated muscular diaphragm, the iris, is continuous through the intervention of the ciliary body; and within the choroid is a nervous membrane, the retina, for the reception and transmission of visual impressions. The cavities formed by these membranes contain the internal refracting media, that is to say, the aqueous humour, the crystalline lens, and the vitreous body, which not only fulfil the optical purpose already assigned to them, but also preserve the shape and tension of the organ. In order to facilitate description, it is customary to apply to the "globe" other terms which are also borrowed from geography. Thus, the geometrical summit or centre of the cornea is called the anterior pole of the eyeball, and the opposite or posterior centre is the posterior pole. An imaginary line from pole to pole, passing through the centre, is the axis of the globe; and an imaginary vertical plane, passing through the centre perpendicular to this axis, is the equator, and divides the eye into an anterior and a posterior hemisphere. The axis of the globe must not be confounded with the axis of vision, which is an imaginary line drawn from the fovea centralis, or functional centre of the retina, to the point looked at. The axis of vision may pass through the cornea either on the nasal or on the temporal side of the anterior pole; and the angle which the two axes form with one another varies somewhat in different conditions. Imaginary planes coincident with the axis of the globe are called meridians; and of these the vertical meridian, which divides the eye into a nasal and a temporal hemisphere, and the horizontal meridian, which divides it into a superior and an inferior hemisphere, are those to which reference is chiefly made by writers. We speak also of the anterior and posterior pole of the crystalline lens, and of its equator, or margin; and we divide the surfaces of the lens and cornea into quadrants, or spaces defined by the intersection of the vertical and horizontal meridians.

The eyeball, thus formed, is connected with the brain through the intermediation of the optic nerve and tracts. It is contained within the bony cavity of the orbit; is supported upon a cushion of connective tissue abounding in fat; is rotated in various directions upon its centre by six muscles which are inserted into its external coat; is covered anteriorly by a delicate mucous membrane, the conjunctiva, which is reflected to line the eyelids, and is also continuous with the mucous membrane of the nasal cavities through the lacrymal canals, and with the integument of the face at the palpebral margins. The surface of the eye is still further protected by the eyelids and their appendages. A sectional diagram of the eyeball itself is given in the frontispiece, and an enlarged view of the ciliary region in Fig. 1.

The sclera, or sclerotic coat (s s, Frontispiece, and *s*, Fig. 1), which forms the posterior four-fifths of the external tunic, is a dense fibrous membrane of firm texture and glistening whiteness. At the posterior part, where it is perforated to admit the passage of the optic nerve fibres and the retinal vessels, and where it is reinforced by the fibrous sheath of the optic nerve, it is about a millimetre in thickness, and it thins off anteriorly, until, near the cornea, it is again reinforced by the tendons of the recti muscles. Its thinnest and weakest part, at which it is most liable to be ruptured by a blow, is immediately behind the insertions of these tendons. The perforation for the optic nerve

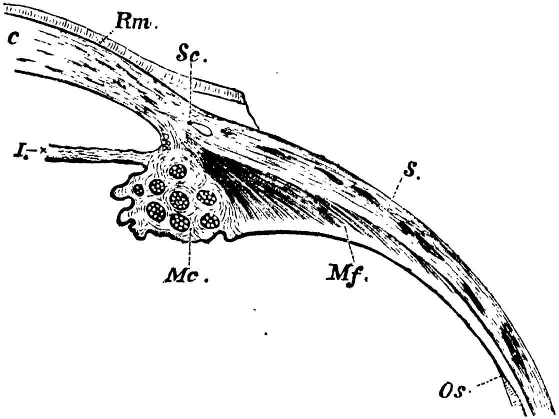

Fig. 1.—Enlarged Sectional View of the Ciliary Region.

s, Sclera; *c*, cornea; I, base of iris; Rm, Reichert's (Bowman's) membrane; Sc, Schlemm's canal; Mc, circular fibres of ciliary muscle; Mf, radiating fibres of ditto; Os, ora serrata of retina.

fibres, or sclerotic foramen, is about a millimetre and a half in diameter, and is situated just below the horizontal meridian, with its centre about four millimetres to the nasal side of the posterior pole. The aperture is partially closed, at the level of the external surface, by a fine web of white fibrous tissue, the lamina cribrosa, which suffers the nerve fibres and vessels to pass through the sieve-like openings in its structure. Anteriorly the sclera is somewhat contracted, so as to form a circular depression (sulcus scleræ) around the cornea; and, just in front of this, it is traversed near its internal surface by a circular channel, Schlemm's canal (sc, Fig. 1), which contains and protects an intricate plexus of veins. The sclera is covered in front by the conjunctiva of the globe; and, as seen through this membrane, constitutes the "white of the eye." In infancy it presents a bluish aspect, having then a degree of translucency which permits the dark colour of the choroid to show through; and in advancing life its whiteness is often obscured by a yellow tinge derived from fatty deposit in the subconjunctival tissue, or possibly in the sclera itself.

The cornea (C, Frontispiece), the anterior portion of the external tunic, is a dense membrane of seemingly absolute transparency, which forms a portion of a smaller spheroid (or ellipsoid) than the sclera, into which it is inserted after the manner of a watch-glass into its setting, the scleral tissue advancing farther anteriorly than posteriorly, and also advancing farther above and below than laterally; so that the cornea, which is circular as seen from within, appears elliptical in its outer aspect, and has a vertical diameter which is some half a millimetre less than the horizontal. Its general thickness is about a millimetre; and its surfaces are parallel in its central region, but they cease to be so near the periphery, where its thickness is about two-tenths of a millimetre greater than in the centre. It has a laminated arrangement, the laminæ being composed of delicate fibres and inclosing numerous irregular spaces or cavities, which contain nucleated cells called "corpuscles" of the cornea, and which communicate freely, so as to form a system of channels for the circulation of nutrient fluid. The proper substance of the cornea is inclosed within two structureless transparent membranes, the external commonly known as Bowman's or as Reichert's membrane, the internal as the membrane of Descemet. Each of these membranes is covered by epithelium, which, on the external one, is continuous with the epithelium of the conjunctiva (*ca*, Frontispiece), the other elements of which membrane terminate at the corneal margin. The healthy cornea contains no blood-vessels, although they often become developed during disease; but it is richly supplied with nerves, which ramify not only in the deeper layers of the anterior epithelium, but also in the proper corneal substance, anastomosing freely and constituting a plexus of great fineness and intricacy. The lymphatics of the conjunctiva form a fine network, which terminates in closed loops at the corneal margin; and with this network the interlaminar spaces in the cornea are believed to communicate freely.

The choroid, or vascular tunic of the eye (*ch*, Frontispiece), lines the posterior three-fifths of the globe, and is merged anteriorly in the circle of ciliary processes. It is in contact with the inner surface of the sclera, to which it is united by a few fibres of lax connective tissue. Like the sclera, it is perforated for the passage of the optic nerve and retinal vessels. The perforation is slightly smaller than that of the sclera, over which it is superimposed, and is bounded by a circle of connective tissue fibres, some of which send out processes that pass between the nerve fibres and are lost in the lamina cribrosa. The choroid consists almost entirely of blood-vessels, supported by a delicate web of connective tissue; but it is abundantly supplied with nerves, and contains bundles of unstriped muscular fibre. The interstices of the stroma are filled by cells containing dark brown pigment, which, together with the blood in the vessels, give to the membrane a reddish brown or chocolate colour. The pigment is often specially abundant around the optic nerve entrance, but its quantity differs greatly in different persons. It is most abundant in dark races and individuals, is comparatively scanty in the fair, and is altogether wanting in albinoes. The choroid is often described as consisting of many layers, but of these only two need be recognised in practice; the external, containing large vessels and abundant pigment, and the internal, containing small vessels or capillaries and comparatively little pigment. The most conspicuous vessels of the external layer are the stellate clusters of veins known as the venæ vorticosæ. These clusters are usually four, sometimes five or six in number; and each one of them is composed of ten or twelve veins which converge to a common central trunk. The central trunks of these vortices pass out through the sclera by oblique channels directed from before backwards, and situated behind the equator, about the junction of the posterior with the middle third of the eyeball. The inner layer of the choroid, the most internal portion of which is called the chorio-capillaris, contains fine or capillary vessels only, and is separated from the retina by a smooth and homogeneous basement membrane.

A short distance in front of the equator, the choroid no longer remains in contact with the sclera, but is elevated into a series of plaits or folds, usually seventy in number, called the ciliary processes (*cp*, Frontispiece). These are arranged radially around the posterior aspect of the margin of the iris; increasing in size from behind forwards, and terminating anteriorly in rounded extremities. Each process is covered, and also the sulcus between each two processes, by the choroid, but a portion of the mass of each process is formed by the ciliary muscle. The processes, taken collectively, constitute the ciliary body; and the part of the eye in which they are situated, and in which the several tunics are united more intimately than elsewhere, is called the ciliary region. This region is very abundantly supplied with nerves and blood-vessels, and, as will be seen hereafter, it is of great surgical importance. Externally, it corresponds with a zone about three millimetres in width, the anterior border of which is concentric with the cornea, and a little more than one millimetre from its margin.

The ciliary muscle, muscle of accommodation, or tensor of the choroid, consists of unstriped fibres, of which the anterior (M*c*, Fig. 1) are arranged in a circle, while the posterior or meridional (M*f*, Fig. 1) radiate in the direction of the processes themselves. These meridional fibres have their origin in a circular tendon, situated at the corneo-scleral junction, on the inner side of Schlemm's canal, and separated from Descemet's membrane by a little connective tissue. The external meridional fibres pursue a course parallel to the inner surface of the sclera, and lose themselves in the choroid, forming connections with the muscular tissue which is dispersed through its stroma. The internal meridional fibres turn somewhat away from the sclera towards the axis of the eyeball, and form an intricate network, which fills up much of each process. The circular fibres pass through and occupy the anterior rounded portion of each process. The function of the ciliary muscle is to effect the alterations in the curvature of the crystalline lens by which the eye is adjusted, or "accommodated" for vision at different distances; but its mode of action will be best considered when the lens itself has been described.

The anterior portion of the vascular tunic, the iris (I, Frontispiece), is a circular vertical curtain or screen, continuous posteriorly by its marginal attachment with the anterior borders of the ciliary processes, and anteriorly, by the ligamentum pectinatum, with Descemet's membrane. These attachments are also called the "pillars" of the iris; and they carry back its origin a little behind the margin of the transparent cornea to the front portion of the ciliary body. The iris is perforated by a circular aperture, the pupil, which admits light into the eye. The diameter of this aperture varies in response to variations in the quantity of light which falls upon it; and its position is not quite central in the iris, but a little below the centre and towards the nasal side. The iris resembles the choroid in general structure, but its more abundant muscular fibres are arranged, some in a circle round the pupil, others in lines radiating from the pupillary to the ciliary margin, so as to form a sphincter and a dilatator of the opening. It is richly supplied with blood-vessels and nerves; and its arteries form two special circles of anastomosis; one, the greater arterial circle of the iris, near the ciliary, the other, the lesser arterial circle, near the pupillary margin. The posterior surface is covered (excepting in albinoes) by a dense layer of cells containing black pigment, so that it is practically impenetrable by light. The anterior surface is covered by pavement epithelium, continuous with that of Descemet's membrane. At birth, the anterior surface of the iris is always blue, even in the dark races; this colour not being due to pigment, but being what is called in optics an interference phenomenon, like the blue of the sky. In a few eyes the original interference blue is retained; but in the greater number a deposit of pigment in the anterior part of the iris stroma commences within a few weeks of birth, and the various familiar tints of grey, hazel, and brown are gradually produced. Sometimes the pigment is irregularly deposited in patches; and the irides of the two eyes of the same person are sometimes differently coloured. The margin of the pupil is somewhat bevelled at the expense of the anterior portion of the iris; so that even in light irides the pupil is bordered by a fine dark ring of the posterior pigment layer, which is generally overlooked against the blackness of the pupillary space, but which may be discovered if sought for, and which, when the pupil is rendered white by cataract, becomes very conspicuous. During part of the fœtal life the pupil is closed by a membrane, the *membrana pupillaris*, portions or filaments of which sometimes remain after birth. If such portions are carefully examined by focal illumination, they will be seen to be attached to the anterior surface of the iris, at some distance from the pupillary margin; and by this character they may always be distinguished from lymph deposits left behind by iritis. In health, and when seen through a healthy cornea, the iris presents a lustrous surface, and an almost infinite variety of fibrillation and colouring, as well as a circular outline and a free mobility of the pupil, which should expand under every passing shadow, and should contract with the smallest increase of illumination. When seen in profile, the iris should project forwards to a scarcely appreciable extent; being kept in this position by the convexity of the crystalline lens, on which it rests except when the pupil is dilated. It should not undergo tremulous movements in response to movements of the eyeball; such tremulous movements, when present, indicating the loss of the support which it naturally receives from the lens and the vitreous body.

perception, and they are directed radially towards the centre of the eyeball, the apices of the cones resting on the pigmented epithelium. In the vicinity of the macula lutea each cone is surrounded by a single circle of rods, but in more peripheral parts of the retina the circle of rods around each cone is triple or quadruple. It is believed that the cones are not only more sensitive to visual impressions than the rods, but that they are also the organs of the perception of colour, which, with one apparent exception, is more acute in the macula lutea than elsewhere; but it can hardly be said that we possess any certain knowledge upon the subject. The conducting layer, or layer of nerve fibres (No. 2), is formed of the fibres of the optic nerve, which leave their sheaths at the lamina cribrosa of the sclera, pass through the scleral and choroidal openings, and bend round in bold curves to fall into the retinal surface. These fibres do not radiate symmetrically; but, the nerve entrance being eccentric, the greater number pass to the temporal side, and are inclined either upwards or downwards, forming curves which meet on the horizontal meridian of the background of the eye, except at the macula lutea, where the fibres stop at its border instead of meeting. It is obvious that, as a mere matter of the quantity and the mechanical distribution of the fibres, the conducting layer must be thicker immediately around the nerve entrance than elsewhere, and that, excepting at the macula lutea, it must thin off gradually to the ora serrata.

The vessels of the retina, both arteries and veins, follow a course which generally resembles that of the nerve fibres. The main divisions pass upwards and downwards from the nerve entrance, and curve around the macula lutea, while smaller branches pass to the nasal side. The vessels divide and ramify in an arborescent manner, which distinguishes them from the approximately parallel veins of the choroid; and they terminate in a capillary plexus, or in loops at the ora serrata. The larger branches are confined to the layer of nerve fibres, but fine twigs are given off at right angles, and sink into the retinal tissue, to form a capillary network which does not penetrate deeper than the internal granular layer. Near the margin of the macula lutea the twigs terminate in loops, and the capillary network itself stops short of the fovea centralis, which is extravascular. The veins mostly accompany the arteries, or lie near them, and the circulation of the retina is almost independent. It does not anastomose with that of the choroid at the ora serrata, but receives some minute twigs from the ciliary vessels at the entrance of the optic nerve into the eye.

The tunics hitherto described inclose an approximately spherical cavity, which is divided into two portions by the crystalline lens and its suspensory ligament. The smaller and anterior portion is subdivided by the iris into the anterior and the posterior chambers (AC and PC, Frontispiece), and contains the aqueous humour; the larger and posterior portion (VB, Frontispiece) contains the vitreous body. The cornea, aqueous humour, lens, and vitreous, are collectively described as the transparent or refracting media. Through them light passes to the retina; and, by their optical properties, it is so arranged as to form defined images upon the layer of rods and cones.

The cavity of the aqueous humour is bounded anteriorly by the posterior surface of the cornea, posteriorly by the anterior surfaces of the ciliary processes, by the zonule of Zinn, and by the anterior capsule of the lens. In this cavity the iris stands as a slightly convex screen with a central perforation, which is occupied by the anterior pole of the lens.

When the pupil is small its margin rests upon the lens, and the aqueous space behind the iris, the posterior chamber, is separated from the aqueous space in front of the iris, or the anterior chamber. When the pupil is dilated, its margin recedes from contact with the lens, and the two spaces are in free communication. The aqueous humour by which both are filled is as nearly as possible pure water, containing no albumen, and, in health, not more than about one part in a thousand of the saline constituents of the blood. The quantity of the aqueous humour is such as to fill the entire cavity, and it is rapidly re-secreted when evacuated by puncture.

The crystalline lens (L, Frontispiece) is a transparent, bi-convex, highly refracting substance, more convex posteriorly than anteriorly, usually about nine millimetres in diameter, and from three to four in thickness, enclosed within a transparent and homogeneous capsule, and suspended vertically from the ciliary processes in contact, when the pupil is contracted, with the posterior surface of the iris. It consists of concentric laminæ, and these laminæ are formed of three or more portions, so that after maceration the lens may either be peeled into layers like an onion, or broken into three or more sectors along lines radiating from its centre to its circumference. The laminæ are composed of fibrillæ, which are flattened hexagons in section, and are finely serrated at their borders in such a manner that the serrations interlock and form a highly elastic and resisting structure. The external laminæ are softer than the internal, a difference which gives rise to a division of the lens into nucleus and cortex, but to these divisions no boundary line can be assigned. The lens becomes harder, drier, and more resistant as life advances; and having been originally colourless, it assumes in old age a yellowish or amber tint. The capsule which encloses it, and which, although continuous, is described as consisting of the anterior and posterior capsule, is a structureless membrane like that of Descemet. The lens is kept in position partly by the equality of pressure in the aqueous and vitreous chambers, and partly by a fine transparent fibrillated membrane (the suspensory ligament or zonule of Zinn), which closes the interval between the margin of the lens and the ciliary processes. With regard to the exact connections of this membrane, some difference of opinion exists; but it is now generally admitted to be a direct continuation of that which has been variously described as the internal limiting membrane of the retina and the hyaloid membrane of the vitreous. According to one view, the suspensory ligament passes only to the anterior surface of the lens, uniting there with the anterior capsule; and a triangular space, the canal of Petit, is left around the lens margin, the anterior wall of this space being formed by the suspensory ligament, the posterior by the vitreous body, and the base by the lens. According to another view, the zonule consists of fibres which interlace in various directions, and pass both to the anterior and to the posterior capsule, so that the canal of Petit has no existence as a separate and defined space. On either supposition there is around the lens margin an area, consisting either of one space, or of several communicating spaces, filled with fluid, and permitting an interchange of fluid between the aqueous and the vitreous chambers. The suspensory ligament thus intervenes between the circle of the ciliary body and the margin of the lens, and furnishes the only manifest medium through which the lens can be acted upon by the ciliary muscle. About the precise method of this action there has been much dispute; but the view generally entertained is that, in the quiescent state of the muscle, the lens is compressed and flattened through the intermediation of the zonule; and that contraction of the muscle, by bringing the peripheral attachment of the zonule forward, relaxes its tension, and permits the lens to assume a more convex outline by virtue of its own elasticity. It is at least certain that the convexity of the lens is increased by the action of the muscle, and that the maintenance of the necessary effort is in certain cases fatiguing or impossible.

Behind the lens the whole of the posterior cavity of the eyeball is accurately filled by the vitreous body VB (Frontispiece), which presents to the naked eye the appearance of a transparent mass of colourless jelly, and which has the same index of refraction as the aqueous humour. The minute anatomy of the vitreous is very simple, and will be referred to in the chapter devoted to its diseases.

Of the conjunctiva, or mucous membrane of the eye and eyelids, which is indicated at *ca* in the Frontispiece, it is only necessary to observe that its ocular portion is separated from the sclera by a lax connective tissue, which becomes more scanty in the vicinity of the cornea, and disappears altogether at its margin, where the conjunctiva also terminates by being firmly attached to the sclera, except that its epithelium alone is continued over the corneal surface. The conjunctiva is very vascular, and its vessels, which are not usually conspicuous, become much and quickly distended by even a small amount of irritation. On the nasal side, near the inner canthus, the conjunctiva presents a fold, the plica-semilunaris, which has its concavity turned towards the cornea, and is more conspicuous in some persons than in others. This fold appears to be a rudiment of the nictitating membrane, or third eyelid, which is possessed by many birds and animals, and it has no special function in man. Still nearer the inner angle of the lids is the caruncle, a small rounded eminence of connective tissue, covered by conjunctiva, and studded by a few fine hairs.

The optic nerve, upon which the eye is dependent for the conveyance of visual impressions to the sensorium, takes its origin by two roots from the corpora geniculata; and these roots, after their union, pass forward on either side, under the name of the optic tracts, to form the chiasma, or optic commissure, in front of which they are called the optic nerves. In the chiasma the fibres interlace in a complicated manner, and it cannot be said that their subsequent course has been fully ascertained. It was at one time taught that certain fibres were bent back at the chiasma, so as to pass from one side of the brain to the other, and that others were in like manner inter-retinal; but that the greater part of the fibres derived from the right optic tract were distributed to the temporal side of the right retina and to the nasal side of the left retina, while those of the left tract went to the temporal side of the left retina and to the nasal side of the right. By this arrangement it was supposed the impression created by an object of vision to the right of the spectator was always conveyed to the left side of the brain, and *vice versâ;* but this ingenious view cannot be said to have been entirely established either by anatomical or by pathological investigation. The optic nerve carries with it from the brain an inner sheath of neurilemma derived from the pia mater, which sends many fine septa into the trunk, and thus divides the fibres into bundles. These septa convey blood-vessels from the neurilemma, so that the capillary circulation of the nerve is derived from, and is continuous with, that of the pia mater. On entering the orbit the nerve receives a second or external sheath from the dura mater, which there splits into two layers, one of them lining the orbit as periosteum, while the other, forming the nerve sheath aforesaid, passes forwards and becomes continuous with the sclera. In the space between the two sheaths, the inner derived from the pia mater and the outer derived from the dura mater, there is yet a third investing membrane which adheres closely to the dural sheath. This third membrane is a prolongation of the arachnoid; and between its two layers there is a narrow space directly continuous with the intracranial arachnoid cavity. The interval between the sheaths derived respectively from the dura and from the pia mater is not completely filled by the hollow process or arachnoid; but there remains also another space, which is directly continuous with the subarachnoid cavity within the skull. In the normal condition this last space is the most conspicuous of all, for it extends quite to the sclera, and, in some cases, especially in myopic eyes, passes into its substance. The cavity within the process of the arachnoid, or the subdural space, is in health an insignificant chink, which terminates before reaching the eyeball; but in certain forms of intracranial disease, attended by effusion into the arachnoid cavity itself, the subdural space may become much distended.

The optic nerve pursues a somewhat curved course along the axis of the orbit, and enters the eye through the already described scleral and choroidal openings. The sheath derived from the pia mater terminates at the lamina cribrosa, or at most sends a few fibres into the choroid. The central artery of the retina pierces the sheaths about half an inch behind the eye, and, with its companion vein or veins, occupies thenceforward an almost axial position within the nerve trunk. At the lamina cribrosa the individual nerve fibres lose their sheaths, and the septa of connective tissue cease abruptly by blending with the lamina; so that the total diameter of the nerve is diminished by about one-half. The uncovered fibres bend round, as already described, to constitute the fibre layer of the retina.

The eyeball is suspended in the orbital cavity, a little on the temporal side of its axis, by six muscles, the four recti (superior, inferior, internal, and external) and the superior and inferior oblique. The four recti and the superior oblique take their origins at the apex of the orbit. The recti diverge to receive the globe, and then, becoming applied to it at a short distance behind the equator, embrace it closely until they are inserted into the sclera by flat tendons at a short distance from the cornea. The insertion of the internal rectus is nearer to the corneal margin than that of the external; and the insertions of the superior and inferior recti are still more remote. The breadth of the tendons varies with the general muscular development of the individual; but the internal is generally the largest and strongest of the recti. The superior oblique ascends to the inner and superior angle of the orbit, where it passes through its well-known pulley, and its tendon then descends at an angle, and passes under the superior rectus, to be inserted into the sclera on the posterior hemisphere, just by the upper margin of the external rectus. The inferior oblique takes its origin from the lower angle of the inner wall of the orbit, near the opening of the nasal duct, and passes somewhat backwards and outwards, below the inferior rectus, to be inserted in a line opposite to the insertion of the superior oblique. The bodies of the muscles are separated from the globe by a fibrous capsule, the capsule of Tenon, which their tendons perforate. This capsule is attached posteriorly to the sclera in a circle somewhat in front of the nerve entrance, and anteriorly is lost in the conjunctiva, near the corneal margin. Where the tendons perforate it they also receive sheaths from it, and carry them to the sclera. The space between the eyeball and the capsule contains lax connective tissue, which permits the free rotation of the globe about its centre, in response to every contraction of its guiding muscles. Together with the structures already described, and with the nerves and blood-vessels of the eye and its appendages, the orbit contains the levator palpebræ superioris, which passes above the superior rectus, to be inserted into the margin of the tarsal cartilage of the upper lid; and the rest of the cavity is occupied by the lacrymal gland, and by connective and adipose tissues which facilitate the ocular movements.

Besides the optic nerve, the eye and its appendages receive sensory branches from the first division of the fifth, and motor branches from the third, fourth, sixth, and seventh nerves, and from the sympathetic. The three chief branches of the first division of the fifth, the lacrymal, the frontal, and the nasal, all send cutaneous twigs to the eyelids and to the conjunctiva, and it is probable that some of these reach the cornea; but the manifest contributions of the fifth to the eyeball are derived from the nasal branch, which gives off the superior or long root of the ciliary, ophthalmic, or lenticular ganglion, and also the two or three "long" ciliary nerves, the course of which will be presently mentioned. The third nerve supplies the sphincter of the iris, the ciliary muscle, and all the muscles of the eyeball excepting the external rectus and the superior oblique. It divides within the orbit into two main branches, of which the superior and smaller passes inwards across the optic nerve to the superior rectus and the levator palpebræ, while the inferior and larger divides into three parts. One of these passes beneath the optic nerve to the internal rectus, another to the inferior rectus, and the third passes forwards between the external and inferior recti to the inferior oblique. From this nerve a short thick branch is given off to the ciliary ganglion, forming its lower root, and two filaments are given to the inferior rectus. The fourth nerve proceeds to the superior oblique, and the sixth to the external rectus. The portio dura of the seventh supplies the orbicularis palpebrarum muscle. The ciliary ganglion, which derives its sympathetic root from the cavernous plexus, and is reinforced from the third and fifth nerves in the manner described, gives off ten or twelve delicate filaments (the short ciliary nerves), which, accompanied by the long ciliary branches from the nasal, lie above and below the optic nerve, and perforate the sclera in a small circle around it. The ciliary nerves, long and short together, pass forwards between the choroid and the sclera, grooving the internal surface of the latter, and ramifying and anastomosing as they proceed, until they reach the ciliary region, where they form an intricate plexus from which the iris, ciliary muscle, cornea, and blood-vessels are supplied. The ultimate distribution of the fibrils from the different sources has been determined by analogy, by experiment, and by the observation of disease. Paralysis of the muscles which are known to be supplied by the third is almost invariably attended by paralysis of the sphincter pupillæ and of the muscle of accommodation, whence it is inferred that these derive their motor power from the same source. Division or injury of the cervical sympathetic produces contraction of the pupil and passive congestion of the eye, whence it is inferred that the sympathetic supplies the dilatator pupillæ and the vaso-motor branches. About the fifth, as a nerve of sensation, there can be no doubt, and there is much reason to believe that it also ministers to distinctly trophic functions. It is at least certain that the nutrition of the eyeball is liable to suffer greatly when the fifth nerve is irritated or diseased.

The blood supply of the eye and its appendages is derived from the ophthalmic branch of the internal carotid artery, and is chiefly returned through the angular vein to the facial, or through the ophthalmic vein into the cavernous sinus. The arteries of the globe are divided into the long, short, and anterior ciliary. The long and short ciliary pierce the sclera in the neighbourhood of the openings for the ciliary nerves. The short arteries, of which there are twelve or fifteen, are mainly distributed in the choroid ; the long, two in number, pass forward under the sclera with little ramification until they reach the ciliary body, when they break up into twigs, which chiefly proceed to the iris to form its greater and lesser arterial circles, and which also supply a zone of fine vessels to the sclera, immediately around the margin of the cornea. The anterior ciliary arteries are derived from muscular branches which pierce the anterior part of the sclera and proceed to the iris. The eyeball, as well as the conjunctiva, probably receives twigs from some of the palpebral branches of the temporal and angular arteries, and some of its veins discharge themselves into the facial vein. Others, which perforate the sclera not far from the corneal margin, course backwards under the conjunctiva, and, together with the trunks of the venæ vorticosæ, proceed to the ophthalmic vein.

The anatomy of the eyelids requires only a cursory mention. Each one is formed by a thin plate of dense fibrous tissue, commonly described as the tarsal cartilage, convex externally, concave internally, and moulded to fit accurately to the contour of the globe. These so-called cartilages are lined by reflected conjunctiva, which is very thin and smooth and closely adherent to them, and they are covered by the orbicularis muscle, and by a thin common integument. At their free borders the lids are rather broad, and are so bevelled that only their anterior margins come into contact when the eyes are lightly closed. From the anterior margin of each lid there projects forwards a row of strong, slightly curved hairs, the cilia, or eyelashes; and within the cilia are the orifices of the meibomian glands, which keep the edges of the lids lubricated by a greasy secretion which forms a barrier to the overflow of tears. The conjunctiva lining the cartilages contains numerous papillæ analogous to those of the dermis; and, where it is reflected from the cartilage to the globe, it forms a loose fold (the retro-tarsal fold), and is thickly studded with minute lymph glands. Near the inner canthus, or angle of the palpebral aperture, there are two small openings, the puncta lacrymalia, situated one on the margin of each lid, and leading to the tear passages. Between the puncta, and nearer to the middle line, filling the angle, is the little fleshy substance called the caruncle, which has been already described. The length, thickness, and abundance of the cilia differ much in different persons; and the integument of the lids is apt to lose its tone, and to fall into lax folds and wrinkles, as one of the changes incidental to declining years.

If we proceed now to the physiology of the eye, we find that its essential function almost precisely resembles the action of a photographic camera. As this, when properly adjusted, produces upon its sensitive plate defined inverted images of the objects to which its lens is directed, so the refracting media of the eye should produce defined inverted images upon the layer of rods and cones of the retina; and the whole of its mechanism is subservient either to this end, or to conducting to the sensorium the impressions which are thus produced. If either the conducting function of the optic nerve, or the perceptive function of the retina, should be abolished, there will be no vision at all; but, whilst the nerve and the retina are healthy, the quality and the acuteness of vision depend upon the transparency of the refracting media, and upon the perfection of the optical images which they form. If the media themselves, though still translucent, have become turbid, vision may be reduced to a simple perception of light; and, even when they are transparent, if the image cast upon the retina should, from any optical fault, be blurred or ill-defined, the impression conveyed to the consciousness will be of a like imperfect character.

Next after transparency of the media, the most essential condition of perfect vision is the preservation of a certain degree of tension or fulness of the eyeball, by which the retina is maintained at a proper distance from the cornea, and both are supported in a regular curvature. If the eyeball were to become flaccid, its shape as a whole, and the curvatures of its different parts, could no longer be preserved, and the ocular images would be subject to distortion, either by the irregularities of the media through which the rays of light were transmitted, or by those of the surface on which the images were received. On the other hand, if the eyeball becomes unduly distended, its contained parts suffer injurious pressure against the unyielding sclera, its internal circulation becomes impeded, and its nervous elements are hindered in the due discharge of their functions, consequences which will hereafter be fully described under the heading of "Glaucoma." It is, therefore, essential to the perfection of seeing that the quantity of fluid within the eyeball, and the relations of that fluid to the containing tunics, should within narrow limits be maintained unaltered; and this is effected by the preservation of a balance between the secretion of fluid within the eyeball, and its removal by exudation or transudation. It is probable that transudation occurs, more or less, in various localities and directions; but the chief seat of the process, according to recent researches, is at the annulus immediately in front of the iris, where the tissue of the sclera, somewhat less dense than in other situations, is rendered still more pervious by the presence of Schlemm's canal, and of the plexus of veins which it incloses. The angle between the apparent margin of the cornea and the anterior pillar of the iris is commonly called the filtration area; and through this area the eye is relieved of most of its superabundant fluid. It is evident, therefore, that anything which tends to thicken the peripheral part of the iris will tend to occupy and fill the angle and to diminish filtration; and such a condition is necessarily produced by dilatation of the pupil. When the pupil is dilated, not only is the iris thickened, but it is usually pushed forward, and hence it comes to be applied, somewhat in the fashion of a valve, to the marginal part of the internal surface of the cornea, and forms a serious obstacle to the access of fluid to the filtration area. In contraction of the pupil these conditions are reversed, the tissue of the iris being stretched and rendered thinner, and being also brought into a more vertical plane, so that it is withdrawn from the corneal margin. Hence, in all cases in which excessive tension of the eyeball from accumulation of fluid is either present or to be apprehended, all agents which produce dilatation of the pupil must be withheld, or used with extreme caution; while agents which produce contraction of the pupil are in high repute as remedies.

As in the camera, the image formed upon the retina is inverted; and the means by which this inverted image is made to convey a correct impression to the sensorium has been a subject of much dispute among philosophers. The most probable explanation is based upon the positions of the retinal bacilli, which are radial to the centre of the eyeball; so that a bacillus in the upper part of the retina, which receives the image of the lower part of an object of vision, may be said to be looking down towards it, and hence to project it into its right position. The same principle would apply, of course, to all other parts of the retinal surface.

The occurrence of single vision with the two eyes is a matter which has also given rise to much speculation, and of which we know little more than that it only happens under certain conditions. We can combine the two images, so as to receive from them a single impression upon the consciousness, only when they are symmetrically disposed upon the two retinæ.

When regarded as a camera, the most common manner in which the eye departs from the normal condition is by a disproportion between the length of the axis of the globe and the optical power of the refracting media, or, in other words, between the power of the lenses and the size of the box in which they are contained. The focal length of the refracting media, and the actual length of the axis of the globe, are two magnitudes not necessarily equal to one another. When they are equal, so that the focus of parallel rays falls upon the retina, the case is said to be one of "emmetropia;" that is, the eye is in true measure or proportion. When they are unequal, either of the two magnitudes may be the greater. When the focal length of the media is greater than the length of the axis of the globe, or, that is, when the globe is short from front to back, so that the focus of parallel rays would fall behind the retina, the case is said to be one of "hypermetropia," or flat-eye. When the focal length of the media is less than the length of the axis of the globe, or, that is, when the globe is long from front to back, so that the focus of parallel rays falls in front of the retina, the case might be described as hypometropia or brachymetropia. This formation, however, is the cause of the condition known as "short-sight;" and the trivial name of "myopia," which was bestowed upon it when its nature was unknown, has become too firmly rooted in the language to be displaced. The whole of these conditions will be fully described in the chapter on "Refraction and Accommodation," and need not now be further referred to.

Apart from such variations, a chief difference between the eye and a camera, or any artificial optical instrument, depends upon the greater extent of field which the eye embraces. This field may be said to extend over 160 degrees from side to side, and over 120 degrees from above downwards; but whereas, in the artificial instrument, we demand clear definition to the margin of the field, or nearly so, in the eye we obtain clear definition only in the centre, over a space which would contain, at the distance of a yard from the cornea, about five letters of the type in which this page is printed. Within such a space a normal eye should be able to distinguish two points separated by a distance equal to about a sixtieth part of the space itself, or by one minute of angular measurement; but, beyond its boundaries, vision becomes progressively more and more indistinct up to the limits of the field. The image formed within the eye has been well compared to a drawing, of which the centre is exquisitely finished, while the marginal parts are merely sketched in outline. Of these we see, indeed, enough to call our attention to any noteworthy objects or phenomena; towards which, as soon as we are thus warned of their presence or occurrence, the direct gaze will be immediately turned, allowing the previous object of regard to pass out of sight, or to lapse into marginal indistinctness. The mobility of the eye almost neutralises, so to speak, the narrowness of the field of exact vision; insomuch that the fact of this narrowness is unknown to the majority of persons, and becomes a matter of surprise when shown by observation or experiment. In technical language, the acute vision with which we see objects upon which the attention is fixed, and the images of which fall upon the central part of the retina, is called *direct vision;* and the imperfect vision, which renders us conscious of the main outlines of lateral objects, the images of which fall upon peripheral parts of the retina, is distinguished as *indirect.* The former is the function of the macula lutea only; the latter, of the whole of the lateral portions of the retina, on which the percipient elements are overlaid by the granular, the ganglionic, and the fibre layers. Besides this gradation of sensibility, the whole surface of the optic disc or nerve entrance, over which the rods and cones are wanting, is absolutely blind; and this blind spot measures not less than six degrees in the horizontal by eight in the vertical direction. If we draw on a piece of paper a small cross as an object, and three or four inches to the right of it a black circle half-an-inch in diameter (as in Fig. 2), and if we look steadily at the cross with the right eye only, while we move the paper slowly to and fro, we shall soon find a distance at which the image of the black circle falls wholly upon the entrance of the optic nerve, and at which the circle itself vanishes. The larger retinal vessels also form "blind lines" radiating from the blind spot; and a point of light may be made to disappear as it passes across or along them. Under certain conditions, moreover, they cast shadows upon the percipient layer, and thus interfere with the perfection of the retinal image. Such kinds and sources of imperfection in seeing are, however, chiefly

Fig. 2.

interesting in their relation to the study of physiological optics; and have little or no bearing, in the present state of knowledge, upon practical medicine or surgery.

R. B. C.

CHAPTER II.

EXAMINATION OF THE EYE.

I PURPOSE to devote this chapter to a description of the methods and instruments by which the eye is examined, with reference to the integrity both of its structures and of its functions. The experienced practitioner, in the majority of instances of disease, will at once be guided to a correct diagnosis by some prominent symptom; but even he will often find the advantage of making a complete examination as a matter of routine, and will be rewarded for doing so by the discovery of conditions which a more superficial observer would be liable or certain to overlook. The acuteness of vision, the manifest refraction, the mobility of the pupil, the position of the iris, the state of the media, the tension of the globe, and the aspect of the fundus, should, I think, be ascertained and recorded whenever the necessary examinations are practicable; while the testing of colour-vision, and the exact measurement of the field, will only be required in a small proportion of cases.

Commencing with simple inspection, the eyelids will be the first parts calling for notice, and they may depart from the normal aspect by being swollen or reddened, either wholly or in parts, by being faulty in position or movements, by containing one or more cysts or tumours, or by redundancy of skin, especially in the upper lids. The cilia may be dwarfed and scattered, or large and numerous, and may be more or less altered in curvature and direction.

The nature and significance of most of the conditions above mentioned will be dealt with in the sequel; but it may be worth while here to call attention to certain derangements of the eyelid movements which fall chiefly under the notice of the physician, but with which it is necessary to be acquainted. In the normal state, the movements of the eyeballs and those of the lids are connected by very intimate associations; which, in certain disorders of the nervous system, are liable to be disturbed or broken through. When a healthy person raises the eyes, either with or without movement of the head, the upper lids are likewise raised, rather as if they were carried up by the eyeballs than as if by contraction of the levatores palpebrarum; and, in like manner, when the eyes are cast down, the upper lids fall with them, and conceal the corneæ from an observer standing in front. In the disease called exophthalmic goitre, the above described harmony of descent ceases to exist; so that, when the eyes are cast down, the upper lids do not follow them, but remain raised as if the gaze were still directed forwards. This symptom, which was first noticed by Von Graefe, and is often called after his name, is highly characteristic; but his observations upon it have been extended, by Dr. Gowers and others, until we have been made acquainted with other conditions in which the natural harmony of action between the upward and downward movements of the lids, and those of the eyeballs, is no longer complete, in which the lids no longer ascend with the eyeballs, or descend with them, although there may be no paralysis of, or loss of volitional control over, either the levatores or the orbiculares muscles. Hence it is always desirable, especially in cases in which disease of any nervous centre is suspected, that the eyelid movements should be carefully noted, and compared with those of the eyeballs themselves.

Having looked at the lids, the surgeon next directs his attention to the conjunctiva and cornea. The conjunctiva in the healthy state and in young subjects is so translucent as to allow the pearly whiteness of the sclera to show through over nearly the whole of its surface, and it contains only a few small blood-vessels. After middle life its translucency is usually impaired by the deposition of fat in the subconjunctival tissue, which gives a yellowish tint to the surface as a whole, and which often becomes collected into small masses on the horizontal meridian of the eyeball, on either side of the cornea, appearing to have been pushed into this situation by the movements of the lids. The visible blood-vessels are also apt to increase in number and magnitude, and may be seen to be of two classes, conjunctival vessels, which ramify in the membrane, and veins which emerge from the eye through openings in the sclera, and course backwards under the conjunctiva to terminate in some of the orbital veins. Such subconjunctival veins indicate a certain amount of passive congestion or of impeded circulation in the choroid; but, within certain limits which only practice can enable the observer to recognise, they are hardly to be looked upon as morbid; while a few enlarged veins in the conjunctiva itself are of no more import than a similar condition in the cheeks. We may, however, find the conjunctiva actively congested, in a degree varying from the presence of a vascular network with white interspaces to that of a general redness and swelling of the membrane, with mucous or purulent discharge. When the congestion is of moderate degree, with little or no discharge, it may be a result of direct local irritation; and, in such a case, the surgeon should very carefully scrutinise the edges of the lids, preferably by the aid of a magnifying glass, in order to ascertain whether any cilium may come into contact with the ocular surface. Inturned eyelashes are often small and pale, and may easily be overlooked. Cases are on record in which a detached cilium had become fixed in one of the lacrymal puncta, from which its point projected in such a manner as to irritate the eyeball. If no source of irritation be found in the lid edges, the whole of the exposed ocular surface must be examined with equal care, in quest of any foreign body which may have been deposited there. Fragments of grit sometimes enter the eyes of travellers, and cause much pain and trouble until they are removed, and other small bodies, such as seeds, or the wing cases of minute beetles, or flies or other insects in their entirety, may easily be introduced in the course of a walk. Generally speaking, the history of the sudden invasion of pain or irritation will point to the nature of such cases; but this is sometimes liable to be overlooked; and, in the presence of any symptoms which may be the result of the lodgment of a foreign body, it is necessary to inspect the cornea in a good light and from all sides, so as to make certain that there is nothing lodged upon it. When this certainty is arrived at, the next step must be to evert the upper lid, on the inner surface of which foreign bodies are frequently discovered, usually a short distance from its margin. The eversion of the lid requires a certain amount of knack, but is not otherwise difficult. The patient is told to look somewhat downwards, and the surgeon takes hold of the cilia and lid margin between the index finger and thumb of one hand, while with the other he places a probe, pencil, or any similar implement, horizontally along the lid surface in a line nearly corresponding with the upper margin of the tarsal cartilage. He draws the edge of the lid forwards, against the probe, and then, directing the patient suddenly to look down as much as possible, he cants the lid upwards around the probe as a fixed point or fulcrum, and exposes the whole of the inner surface. All manipulations of this kind are much facilitated by the action of cocaine, which may be applied most conveniently in the form of a wafer containing a fiftieth of a grain of the hydrochlorate, placed within the conjunctival sac and permitted to remain for ten minutes in order that its effect may be produced. Before everting the lid, it is well to place at hand a fine spatula or pair of forceps, by which any foreign body, if discovered, may be removed at once. The conjunctival sac of the lower lid should also be examined, the lid being drawn away from the eyeball for this purpose, and the patient looking alternately upwards and downwards, by which movements all parts of the sac will be exposed. Very unexpected articles will sometimes reward this kind of search, and I once found under the upper lid several short ends of sewing cotton, which had evidently been placed there by the patient herself, as an easy means of creating an apparent inflammation. Foreign substances are sometimes concealed at the very summit of the upper retro-tarsal fold, above the upper margin of the cartilage, so that they are not exposed by its eversion; and such things may be sought for by the curved middle portion of a hairpin, carried gently round the angle of conjunctival reflection. Further details on these subjects will be given in the chapter on Injuries.

Congestion of the conjunctiva being present, and no foreign body being discovered to account for it, the next step in the examination is to ascertain whether it is limited to the conjunctiva, or extends to deeper tissues. For this purpose, the surgeon places his finger against the lower lid, and pushes it a little upwards, at the same time exerting gentle pressure. He then glides the lid quickly down, maintaining his finger pressure in such a way as to empty the conjunctival vessels. If the congestion be limited to these, the finger pressure will produce a perfectly blanched track right up to the corneal margin, which track, in another second, is obliterated by the return of blood into the emptied vessels. If, however, the congestion is not limited to the conjunctiva, but extends, as in keratitis or iritis, to the zone of fine vessels in that portion of the sclera which immediately surrounds the cornea, then the portion of the bleached track in contact with the corneal margin will be pink instead of white, the vessels of the sclera in this region being protected against the finger pressure so that they are not emptied by it, and being too small, even when distended, to be visible individually, or otherwise than as a pink annulus or zone. If the finger pressure empties veins which emerge from the eyeball, as in cases of internal congestion, these, of course, will refill in a direction from the corneal margin towards the finger; while the vessels of the conjunctiva itself will refill in the opposite direction, from the finger towards the corneal margin.

The characteristics of the healthy cornea are perfect transparency, and such polish that the surface, acting as a convex mirror, returns diminished erect images of all objects in front of it. The transparency permits the fibrillation and colours of the iris to be seen with absolute distinctness; and, the patient being seated opposite a window, the polish affords a reflected image of it, or, if he stand at a proper angle, of the head of the observer. These conditions may be departed from by disturbance and consequent cloudiness of the surface epithelium, impairing both the transparency and the reflections; by general or localised opacity, or by the presence of blood-vessels, which may either be directed from the margin to some single point, or may be closely packed together, with no visible interspaces, over certain portions of the membrane, usually in two crescents, one at the upper and the other at the lower portion of its margin, or may be distributed in branches, separated by manifest interspaces, and derived from trunks which mainly enter the cornea from above. Opacities may be either scars, the remains of former ulcers, or may be interstitial, the effects of cell proliferation, or may be produced by abscesses between the laminæ, or by ulcers, which are, in many cases, left by abscesses which have burst externally. Both abscesses and ulcers are, as a rule, surrounded by zonular turbidity; but there are instances to which this does not apply, and ulcers which are progressive, or dependent upon complete failure of local nutrition, are sometimes only discoverable as solutions of continuity. Such ulcers are of two kinds, the one circular, which may be found upon any part of the corneal surface, and somewhat resembles the appearance that would be produced by removing a fine circular chip from a piece of glass; the other crescentic, concentric with the corneal margin, found usually in the decline of life, and having a tendency to extend at both extremities, so that the whole of the cornea may be, so to speak, trephined by it. In certain conditions, too, chiefly in the so-called "punctated keratitis" which accompanies serous iritis, the cornea presents opacities on its posterior surface; and these are formed by a congeries of minute circular dots, arranged in a form which is generally pyramidal, with its apex towards the pupil, and its base towards the lower margin.

In order to discriminate between these several conditions the use of a magnifying glass is in most cases essential; and the glass should generally be aided by "focal illumination," that is, by the concentration of light upon the part under examination. Such concentration is effected by means of a lamp and a second convex lens, arranged as shown in Fig. 3. By slight movements of the condensing lens the pencil of rays is caused to fall upon the surface at different angles and from different directions, as the case may require. The single magnifying glass shown in the figure may often be advantageously replaced by an achromatic doublet of half an inch focal length, by which much enlargement and a flat field may easily be obtained. The ophthalmoscope will also render valuable help in the examination of the cornea, but an account of its uses for this purpose must be postponed until after the instrument itself has been described.

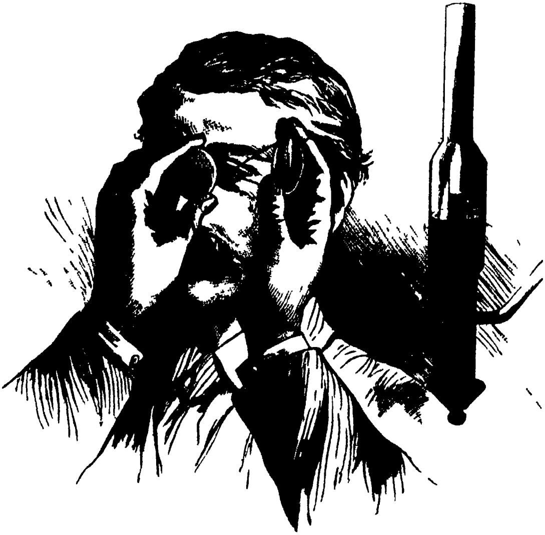

Fig. 3—Examination by Lens, and Focal Illumination.

The cornea having been inspected, attention is next given to the aqueous humour and the iris. The former, in health, is so transparent as to be invisible; but it may be rendered turbid by inflammatory deposits or by blood, and may conceal the surface of the iris even although the cornea is transparent. A clue to the nature of such cases is usually furnished by the reflections from the corneal surface, which, if the anterior epithelium retain its polish, will usually be but little diminished by underlying opacity. In iritis, the aqueous humour is generally sufficiently turbid to alter the apparent colour of the iris as seen through it, so that a blue iris will appear green, and so on. The character of such appearances is shown by paracentesis of the anterior chamber, which, by evacuating the yellow and turbid fluid, restores the surface of the iris to its proper colour.

When the cornea and aqueous humour are sufficiently transparent, attention must next be directed to the iris and pupil. The surface of the iris should be bright and polished, showing its fibrillation and colouring with perfect distinctness, and the pupil should be of medium size and circular, and should respond freely to variations of light. The first point may be distinguished by simple inspection, the second requires a greater amount of care. It is necessary that the eyes should be examined singly, because the pupil even of a blind eye may vary in unison with the variations of its seeing fellow. One eye should, therefore, be covered by a folded towel or handkerchief, sufficiently thick to exclude light, and held gently over the closed lids without pressure. The patient should be seated opposite a window, and the surgeon should place one of his hands in such a manner as to cast its shadow over the eye under inspection. Under this shadow, the pupil should somewhat slowly dilate; and, on the hand being suddenly withdrawn, the pupil should contract more rapidly. The patient should then be told to look straight outwards at some distant object, and then suddenly to turn his eye inwards towards the tip of his own nose; and here again contraction should occur in the act of accommodating for the near object. Dr. Argyll Robertson was the first to point out that, in certain cases, the pupil loses its contractility to light, but still contracts in accommodation. Such a condition is often described as the "Argyll-Robertson pupil," and, notwithstanding the excruciating barbarity of the phrase, it is necessary to be acquainted with its meaning. A case has been recorded by Mr. Jessop,* in which abduction of either eye was attended by dilatation of its pupil, and adduction by contraction, alike independently of light and of accommodation.

Before terminating the inspection of the iris, it is necessary to observe whether it be steady or tremulous; and also whether it retains its approximately vertical normal position, or is displaced either forwards towards the cornea, or backwards towards the vitreous chamber. It may also become manifest that the outline of the pupil is no longer circular; and the chief deviations from circularity are that it may be oval, with its major axis horizontal, as in some cases of glaucoma, or that it may be altered in shape by adhesions to the surface of the anterior capsule of the crystalline lens. Adhesions may often be rendered more conspicuous by focal illumination or by the ophthalmoscope; but, before proceeding to the employment of the latter instrument, it is well to determine the acuteness of vision. The examinations made with this view are less trustworthy immediately after the eye has been exposed to strong light, or after its circulation has been disturbed by the estimation of tension.

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* Trans. Oph. Soc., vi. 378.

Acuteness of vision is determined by the size of the object which the eye can see clearly at a given distance. For many reasons of manifest convenience, printed letters are usually selected as test-objects; and it has been found by experience that a normal eye, in moderate illumination, can readily decipher letters of such a size, and placed at such a distance, that their limbs or parts subtend a visual angle of one minute, and each letter as a whole a visual angle of five minutes. A set of test-types (Appendix A) contains a series of such letters, uniform in outline, and of such sizes that they fulfil the prescribed conditions at the different distances indicated by the numbers which they respectively bear. Thus, No. 6 subtends the required visual angle at six metres, No. 12 at twelve metres, No. 24 at twenty-four metres, and so on. A person with normal vision, separated from the letters by a distance of six metres, should read No. 6 without difficulty, but should not be expected to read No. 5. Hence the acuteness of vision can be readily expressed by a fraction, the numerator of which expresses the distance of the patient from the types, while the denominator expresses the number of the smallest type which can be certainly read at that distance. Thus, if the patient were placed at six metres, six would always be the numerator. If he could read No. 6 type, six would also be the denominator, and his acuteness of vision would be equal to $\frac{6}{6}$ths, or unity, the normal standard. If he could only read No. 12, his acuteness would be only $\frac{6}{12}$ths, or one-half of unity; and if he could only read No. 24, his vision would be only $\frac{6}{24}$ths, or one-fourth of unity. In the actual conduct of the examination each eye must be taken singly, the one which is not being tested being covered by any opaque material, but preferably by a piece of ground glass, which may be placed in a trial frame for spectacles. The acuteness of vision may be apparently reduced by abnormal refraction; and hence the examination is not complete until each eye has been assisted, as far as may be possible, by a lens. We then describe the result first obtained as the acuteness, and the result obtained with lenses as the "corrected" acuteness of vision. In note taking, the letter V is often used as the symbol for the former, and the letters *c*V for the latter. Thus the entry, "$V = \frac{1}{4}$, $H = 4{\cdot}0$, $cV = \frac{1}{2}$," would mean that an eye with apparently very defective vision, only able to read letters of No. 24 at six metres, was hypermetropic to four dioptres, and, when aided by a convex lens of this power, had its vision raised to $\frac{1}{2}$, so that it was enabled to read No. 12 at the same distance. When the acuteness of vision has been thus tested on distant objects (for which purpose a range of ten feet is enough if more cannot be obtained), it should also be tested by "Reading-types" (Appendix A), held in the hand, and then with the help, in persons after middle age, of magnifying spectacles. The note would then run, "reads No. x with lenses of $+x{\cdot}0$, at x inches distance." On all this part of the examination full details will be found in the chapter on Refraction and Accommodation, to which the reader is referred for further particulars, and for more complete instructions with regard to methods of procedure.

Acuteness of vision, as thus determined, refers only to the central part of the retina; and there are certain diseases of the eye in which lateral vision is the first to suffer. In order to measure the extent of the field with exactness, and especially in order to discover isolated patches of blindness, an instrument hereafter to be described as a perimeter is required; but a rough general test, sufficient for a very large number of cases, is obtained in the following way: The patient is directed to stand with his back to a window, and the surgeon stands opposite to him, with the two faces about two feet apart. The patient is directed to close, or to cover with one hand, the eye not under examination, and to look steadily with the other at the eye of the surgeon; looking, of course, with his right eye at the surgeon's left, with his left eye at the surgeon's right. The surgeon looks steadily at the uncovered eye of the patient; and, while doing so, holds up his two hands, one on either side of his face, on a level with his eyes, and midway between the patient and himself. The hands should be held horizontally, the fingers pointing inwards, and they should be so far separated that the surgeon cannot see them himself. They should then be gradually brought together, a slight movement being at the same time given to the fingers. If the patient sees them as soon as the surgeon, the fields of vision of the two are co-extensive; but, if the patient does not see them until after they have become visible to the surgeon, the patient's field of vision is contracted. It will often be found that such contraction exists chiefly on the nasal side of the field; but, if it be unmistakably present in any direction, it will as a rule be advisable to employ the perimeter, and to obtain a precise chart for future comparison and reference.

Assuming that the examination up to this point has revealed impairment of vision in one or both eyes, and that no explanation of such impairment is to be found in the superficial parts of the organ, the investigation must be carried farther by means of the ophthalmoscope. Before explaining the uses of this instrument, it will be necessary to devote some space to its history, and to the principles of its construction and application.

Until what may be described as a very recent time, it was believed, even by philosophers, that the blackness of the pupil of the human eye was due to the complete absorption by the contained pigment of the entering rays of light, so that none of them were permitted to return; and the *tapetum lucidum*, which exists in the eyes of so many of the lower animals, was regarded as a special provision against this complete absorption. Considering that there is no known substance which absorbs all the light it receives, and reflects none, it is difficult to believe how such an explanation could ever have been accepted; but it was first proved to be erroneous by Mr. Cumming,* a student of the London Hospital, who showed that a certain amount of light was returned from the human eye under given conditions. Mr. Cumming's premature death prevented him from following his inquiry farther; but, about 1847, a complete ophthalmoscope was constructed by the late Mr. Charles Babbage, who succeeded in looking into the interior of the eye, and who took his instrument to an ophthalmic surgeon then of much repute, one who was, indeed, interested by the solution of the optical problems involved, but who, unluckily, said that the invention would be of no practical value. Mr. Babbage had worked simply from the point of view of a mathematician; and, on being told that what he had done was useless, threw it aside for other matters. Four years later, in 1851, another form of ophthalmoscope was constructed by Professor Helmholtz, whose invention, fortunately for the world, fell into the hands of an ophthalmic surgeon who was capable of appreciating it. It was soon found that the illumination afforded by Helmholtz's instrument was insufficient for many purposes; and after a while, the original ophthalmoscope of Babbage was re-invented, so to speak, by Professor Ruete, and has ever since held its ground as an indispensable instrument of diagnosis. It consists of a mirror, centrally perforated, to which different lenses are added as adjuncts for different purposes. The material and curvature of the mirror, the character and diameter of the aperture, the number of the lenses and the means of inserting and removing them for different requirements, have given rise to an almost infinite number of variations of the instrument, variations many of which have been called by the names of the men who have suggested them. There is not one of these variations which contains even the germ of a new principle, or which possesses any greater merit than that of being a more or less ingenious adaptation of familiar contrivances.

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* "On a Luminous Appearance of the Eye," 1846.

Prior to the invention of the ophthalmoscope, the interior of the human eye was invisible, and seemed to be black, for the simple reason that all the light reflected from it was returned to the point from which it was received. If, for example, the eye B (Fig. 4) was looking at the flame of a candle A, it would receive from that flame a considerable pencil of rays; and these rays, by the refracting action of the media of the eye, would be united to form an inverted image of the flame upon its retina, at the point C. From this image abundant light would return, but the returning light would be as much subjected to the action of the refracting media as the entering light had been in the first instance, and would therefore all be carried back to the candle flame. The flame and its retinal image, in the case supposed, would be conjugate foci of the optical apparatus of the eye itself; and, outside of the track of the rays going and returning, as at O, no

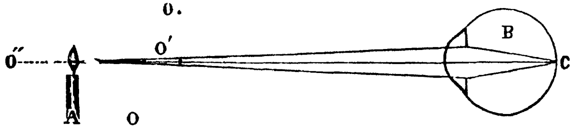

Fig. 4.

light could be perceived. If, however, the observer placed himself within this track, as at o′, his head necessarily intercepted the entering rays, and the eye at which he was looking would no longer receive any light from the flame, but only the small amount which would be reflected from his (the observer's) cornea. This would not be sufficient for any purpose of vision or illumination, and so the pupil would appear dark. If, on the other hand, the observer placed himself on the farther side of the flame, as at o″, so that it came between him and the eye observed, he would no longer intercept the entering rays, but the effect of the returning rays would be overpowered by those proceeding to his eye directly from the flame. The observer would see the candle flame, through which he might not be able to see even the exterior of the eye, much less the interior.

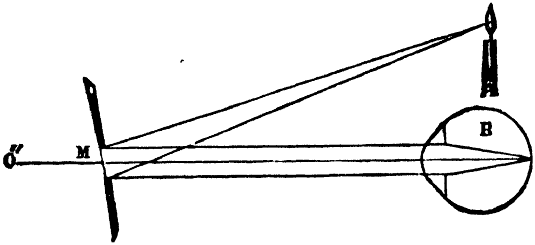

Fig. 5.—Arrangement of Ophthalmoscope.

The ophthalmoscope is neither more nor less than a contrivance for removing the light out of the line of vision, without losing the effect of its illumination. The necessary arrangement is shewn in Fig. 5, in which B is the observed eye, o″ the position of the eye of the observer, and A the flame. The latter, instead of being interposed between the two eyes, is placed at the side of the eye B, and somewhat behind it, and a mirror M, with a central perforation, is held obliquely between the two eyes. The mirror, being held at a suitable angle, receives light from A and directs it into B, the rays reaching B along the line M B, and as if proceeding from a distance equal to the sum of A M and M B. They will form an image of A upon B's retina, and the rays returning from this image will return along the track B M, and would unite, if they encountered no obstacle, at a point as far behind M as A is in front of it. The rays, thus returning, pass through the perforation in the mirror, and behind it they encounter and are received by the eye of the observer at O″, which, in certain conditions, is able to utilise them for purposes of vision, and to see the interior of the eye B, from which they proceed.

In Helmholtz's original ophthalmoscope, the mirror was not perforated, but was simply a plate of polished glass, transparent over all its surface. The illumination afforded by one slip was so feeble as to be of little practical utility; and second and third slips were added for its reinforcement. Even with this addition, the illumination was still insufficient for most requirements, and the improvement effected by Ruete was the introduction of an opaque mirror, of a more strongly reflecting character, and furnished with a central perforation. The mirror may be of steel brightly polished, or of silvered glass; and, in the latter case, the perforation may be either complete, through both glass and silvering, or it may be limited to the latter.

It has just been said, that the light returning through the mirror, from the observed eye, may, under certain conditions, be utilised by the eye of the observer for visual purposes. A reference to the figure will show that the rays in question are combined to form a convergent pencil; and such a pencil cannot be united upon the retina of a normal eye, which is capable of uniting only parallel rays when in a state of rest, or divergent rays by an exercise of accommodation. The pencil under consideration must therefore be rendered either parallel or divergent, before any details of the background of the eye B can be rendered visible to the observer. This can be effected by two different methods, which form the foundations of the two methods of ophthalmoscopic examination.

In the first method, assuming the distance A M to be six inches, the rays of light, when they reached the mirror, would be convergent in such a degree that they would unite in a focus at a point six inches behind it. The rays of light issuing from an emmetropic eye would, when the eye was passive, be parallel; but in the suggested case the eye is supposed to be looking at the image of the flame in the mirror, and therefore to be accommodated for an object which is really six inches in front of the mirror, and apparently six inches behind it. The convergence of the issuing rays would be the result of this accommodation, and would unite them at a point twelve inches in front of the eye of the patient. A concave lens, having a negative focal length of six inches, and occupying the mirror aperture, would render these rays parallel, and the eye of the observer, immediately behind the mirror, would receive them in a parallel condition, and being supposed to be passive and of normal refraction, would unite them upon its retina to form an image of the retina of B. If the patient is using no accommodation no concave lens would be required, and the observer would see the retina of B as an actual object, in its natural position, and magnified by the action of its own crystalline lens. This is called the "direct" method of examination; and except in rare cases of very high myopia, presently to be referred to, it furnishes an "erect" view of the eye under observation. Every part of the fundus is seen in its natural position, and in its true relation to the other parts around it.

Assuming the concave lens not to be interposed, the rays of light returning from A would, it has been shown, be convergent towards a point behind the mirror, and at this point, if not interrupted in their course, they would form an inverted aërial image of the background of B, precisely analogous to the inverted image of any distant object which is formed by holding up a convex lens towards it, at a sufficient distance from the spectator; or precisely analogous to the inverted image formed on the glass screen of an ordinary photographic camera, or to that formed within the eye itself. This image, however, being formed at 12 inches from the eye, would be very large, and the total quantity of light forming it would be so diluted, from being spread over the large surface, as to render the proper discrimination of details difficult or impossible. But if a rather strong convex lens, say of 2 inches focal length, be held near to the cornea of the eye B, so as to intercept the returning rays, these will be compelled to a more rapid convergence, and will be united to form an image at a distance from the lens which will be slightly less than its own focal length. Such an image will still be inverted, but it will be much smaller, and, in consequence, much more brilliant, than that which would have been formed if no lens had been interposed. The observer, placed at a convenient visual distance, will see this small but bright image, and will be able to perceive distinctly the most important of its peculiarities. This is called the "indirect" method, in contradistinction to that first described. Its distinguishing feature is that the interposition of a strong convex lens is employed in order to form a small and bright aërial image, which, and not the actual background of the eye under observation, becomes the object of vision. The image seen in the indirect method is always inverted, its upper portion corresponding to the lower portion of the interior of the eye under examination, its right hand portion to the left of the actual structure, and so on.

If the illumination can be so arranged, in the direct method, that the examined eye does not receive an image of the flame, as of an object at a definite distance for which it is accommodated, the rays of light will not issue in a convergent pencil unless the eye itself is myopic, but will issue in a parallel pencil from an emmetropic eye, and in a divergent pencil from one which is hypermetropic. For explanations of these technicalities, and for diagrams illustrative of their meaning, the reader is referred to the chapter on Refraction and Accommodation, the subject matter of which must be mastered before the uses of the ophthalmoscope can be fully understood. The necessary arrangement can be made without difficulty, by such a curvature of the mirror, and such a distance between it and the flame, that the rays reflected into the examined eye cannot be united into a focus upon the retina of the latter. A mirror of sufficient concavity will furnish the examined eye with a pencil of convergent rays, which will meet in its refracting media before they reach its retina, and will then overcross so as to form upon the retina merely a patch or dispersion circle of light, affording sufficient illumination, but not compelling adjustment of the eye as for an object of vision. The examined eye will then be in a passive condition, so that, if it be emmetropic, the pencil of light returning from it will be parallel; if it be hypermetropic, the returning pencil will be divergent; and if it be myopic, the returning pencil will be convergent. In the last two cases the degree of convergence or of divergence, that is, the distance of the point in front of the examined eye or behind it, in which the rays would unite if sufficiently prolonged, is the measure of the degree of hypermetropia or of myopia respectively.

In the case first supposed, when the examined eye is emmetropic, and the rays of light issue from it in a parallel pencil, such a pencil will be united upon the retina of an emmetropic observer, who will obtain a perfectly clear and defined image of the background of the examined eye without any other optical assistance than that of the perforated mirror, and without any exercise of his own accommodation. In the second case, when the examined eye is hypermetropic, and the issuing pencil is divergent, this divergent pencil could be united upon the retina of the emmetropic observer by means of his accommodation, always supposing that the degree of hypermetropia was not in excess of the observer's power to exercise that function. In the third case, when the examined eye is myopic, and the issuing pencil is convergent, this convergent pencil cannot be united by an emmetropic observer without the aid of a concave lens. In practice, and in explaining the use of the ophthalmoscope, it is most convenient to assume that the observer is emmetropic, and that his eye is passive as regards accommodation. When the facts have been stated upon this basis, it is easy to understand the differences which will be produced by any form of ametropia, or by the exercise of accommodation, in the case of the observer We start, however, with the assumption that the observer is emmetropic, and that his accommodation is absolutely relaxed.

With this assumption the ametropia of the eye B would be expressed by the power of the lens which rendered the pencil of rays issuing from it parallel; and, in order to measure the actual ametropia, the lens in question is supposed to be placed in the nodal point of the examined eye itself. In all practical applications, however, lenses are placed at a definite distance in front of the cornea, and the distance between the lens and the cornea must be allowed for in calculating the result. If the eye B were myopic to such a degree that its farthest point of distinct vision was only 6 inches from its cornea, a lens of 6 inches focal length, placed in the nodal point of the eye itself, would at once correct the myopia and afford expression to its degree. But in all practical applications, whether in the ophthalmoscope of an observer or in the spectacle frame of the patient, the correcting lens must be something like an inch in front of the nodal point, and so, in the case supposed, it must be stronger in proportion to this distance, that is, it must have a focal length of 5 inches instead of 6. Conversely, in the case of a like degree of hypermetropia, the correcting convex lens must be weaker than the ideal requirement in the same proportion, that is, it would have to be of 7 inches focal length instead of 6. The nearer the correcting lens, either in an ophthalmoscope or in spectacles, can be brought to the eye of the patient, the smaller will be the difference between the actual and the practical degree of ametropia.

It follows from what has been said that, if the eye B be emmetropic, a perfectly clear view of the details of its fundus will be obtained, in the direct method, without the use of any correcting lens; but that, if it be ametropic, such a clear view can only be obtained when the ametropia has been corrected by the interposition of a convex or concave lens of power suited to the particular case. The best position for this correcting lens is immediately behind the mirror aperture. If the observer, on looking into the eye, either does not see details of the fundus, or sees them only in a blurred and confused manner, his next step is to place a lens behind the mirror, and to try a sufficient number in succession until he arrives at that which presents him with the most definite image.

It has already been shown in the diagram, and will be manifest on reflection, that the mirror must be placed obliquely in reference to the eye that is observed, as otherwise it could not illuminate this eye from a lamp flame placed laterally. It is important, nevertheless, that the obliquity of the mirror should not be shared by the correcting lens behind it, since an obliquely placed lens affords distorted images of the objects which are seen through it. Hence the mirror of the ophthalmoscope must be independent of the lens holder, and must be capable of being inclined without affecting the position of the latter.

The ophthalmoscopes in ordinary use are mechanical contrivances fulfilling, more or less completely, the several requirements indicated above. They possess mirrors of various characters for different requirements, and lenses which are usually arranged in revolving discs, so that any one which is wanted can be brought over the mirror aperture. It has of late years been almost a *conditio sine quâ non* that every rising ophthalmic surgeon should "contrive" a new ophthalmoscope, and hence the forms of them are legion. The one which seems to me to be beyond all comparison the best is a model originally designed by Dr. Loring, and modified by Dr. Noyes, both of New York. It is somewhat more expensive than many others, but a good ophthalmoscope will last a careful man a lifetime, and there are few things in which the practice of cheese-paring is less desirable than with regard to important instruments.

The Loring-Noyes ophthalmoscope is made in this country by Mr. Hawksley, and is shown of one-half the actual size in Figs. 6 and 7. It has a handle A, of sufficient size and weight to be firmly grasped,

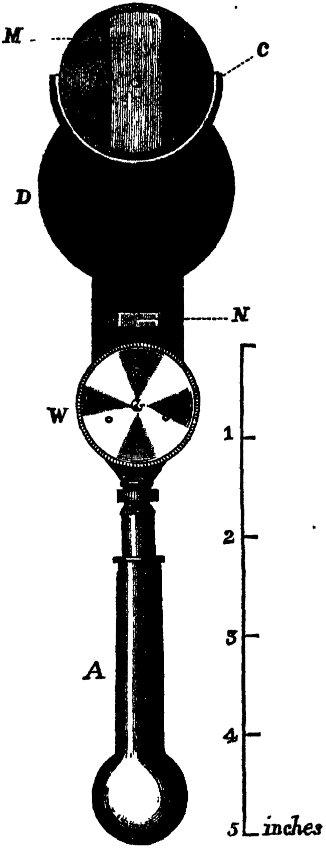

Fig. 6.

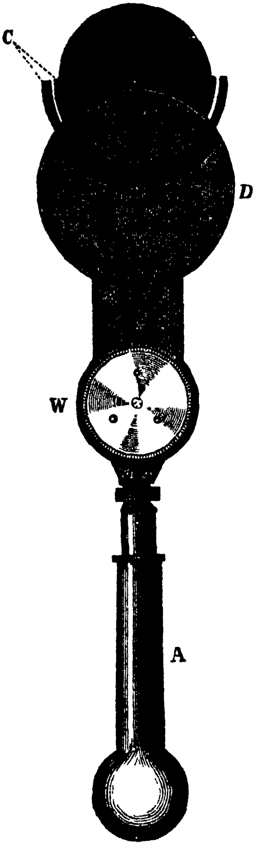

Fig. 7.

and to balance the other parts of the instrument, thus doing away with the common fault of "top-heaviness." At its upper end it has two semicircular clips *c c*, into one of which a cylindrical lens from the test case may be inserted during the examination of astigmatic eyes, while the other receives the mirror. Beneath the two clips are two revolving discs in close apposition, contained within the case D, and moved by the two milled wheels W, which are readily distinguished by the touch, the anterior being of somewhat larger diameter than the posterior. The anterior disc, or that nearest the mirror (Fig. 8), contains sixteen apertures, each seven millimetres in diameter. One of these is left empty, the others are filled by convex lenses ranging at dioptre intervals from one dioptre to seven, and by concave lenses ranging from one dioptre to eight. The second or posterior disc (Fig. 9) contains five apertures, each of seven millimetres, of which the central one is empty. The two on either side of the centre contain one a convex and the other a concave lens, each of

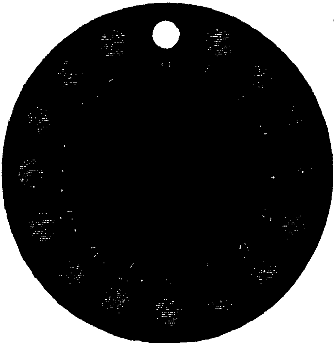
Fig. 8.

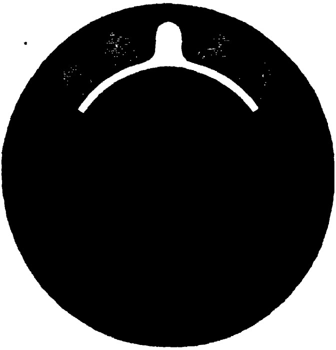
Fig. 9.

half a dioptre; while the two outer apertures contain one a convex and the other a concave lens, each of sixteen dioptres. In both discs the concave lenses are to the right, the convex lenses to the left of the empty aperture; so that turning either disc from left to right brings a succession of convex lenses before the sight hole, while turning to the left brings a succession of concaves. The two discs between them, either singly or by combinations of two lenses, afford half-dioptre intervals from one half to eight convex, and from one half to nine concave, and dioptre intervals onwards to twenty-three convex and twenty-four concave. The way in which this is effected requires a moment's consideration.

Assuming that the observer starts with the empty apertures of both discs before the sight hole, and that he requires a convex lens, he first places his forefinger upon the edge of the larger or anterior milled wheel, and turns it gently to the right. As each successive lens becomes centred before the sight hole, the revolution of the disc is perceptibly checked by a slight catch, which marks the point which it has reached, but does not in the least arrest a farther movement. The successive catches mark the arrival before the sight hole of a succession of convex lenses, at dioptre intervals, until a power of seven dioptres has been reached; but if, during the progression of this series, it is desired to employ a smaller interval, the finger is shifted to the smaller or posterior disc. One movement of this to the right brings forward a half-dioptre convex lens, one movement to the left brings forward a half-dioptre concave lens, so that the observer can either strengthen or weaken by half a dioptre the lens previously in use, and contained in the anterior disc. When the limit of seven dioptres convex has been reached, the observer rotates the posterior disc two steps to the right, and then continues the rotation of the anterior disc as before. The two steps of the posterior disc have brought convex sixteen before the sight hole, superimposed upon convex seven in the anterior disc; but one movement more of the latter brings up concave eight, which obviously reduces the sixteen to eight convex, or the next step to the seven which had been already reached. As rotation of the anterior disc to the right continues, the concaves diminish by dioptre intervals, and consequently take less and less from the strength of the convex sixteen, until the arrival of the empty aperture leaves it undiminished. Following the empty aperture comes convex one, which converts the sixteen into seventeen, and so on in succession until convex seven is in front of the sixteen, and a total of twenty-three dioptres has been reached. If concave lenses are required, the observer rotates the wheels in the opposite direction, from right to left instead of from left to right, and the process above described is repeated in a reverse direction. There is no other ophthalmoscope, as far as I am aware, which affords the same variety and extent of combinations by the same simplicity of movement; for this, although a little complicated in description, is extremely simple in reality, and is readily learned so completely that the observer will keep count of the power he is using at any moment, and will not require to remove the instrument from his eye to see what lens or lenses are before the sight hole. The only instrument which affords an equal variety of lenses is that of Mr. Couper, in which every lens is single, and the whole of them are arranged on a sort of staff of formidable dimensions, which carries a mirror at one extremity, and has the lenses attached to an endless chain, by which they are brought in succession over the mirror aperture. Mr. Couper maintains, I believe, that single lenses are better than combinations, but I am unable to agree with his contention. The very finest optical work, that of microscopes and telescopes of the highest powers, is done by combinations containing numerous lenses, and could not be done otherwise; so that, as far as seeing an object under a magnifying power of twelve or fourteen diameters is concerned, there can be no possible objection to a combination of two. When the ophthalmoscope is used for the measurement of refraction, the use of two lenses does indeed introduce an element of error, but the amount of this error is so small that it may be safely neglected in practice. In estimating an ametropia of four dioptres, or ten inches, the extreme of error which could arise from the employment of two lenses rather than of one would be equal to $\frac{1}{228}$th of the whole amount, and would be less than would be produced by an accidental variation, to the extent of one millimetre, in the sitting of a spectacle frame upon the nose.

A special feature of the Loring ophthalmoscope is the "tilting" mirror, which is seen from the front in Fig. 6. This mirror is simply a circular one, the lateral margins of which have been cut away, and which is mounted on two pivots on its vertical axis, in such a manner that it can receive sufficient inclination while the discs which carry the lenses are not themselves inclined. It is further mounted upon a circular plate of metal, which fits into the clip and can be rotated in it, so that the axis of the mirror can be varied to suit the precise position of the flame. This arrangement is often of great value in the examination of patients who are confined to bed, and in whom it is very difficult to obtain the position of the flame which is secured in the consulting room.

In the examination by the direct method, the mirror and the eye of the patient must be brought as close as possible to one another; and it follows that the only light which can enter the pupil of the examined eye is that which proceeds from the annulus of mirror immediately surrounding the perforation. The light proceeding from the peripheral parts of the mirror would not enter the pupil, but would be lost upon the surface of the iris. Hence, if the perforated or non reflecting part of the mirror were larger than the pupil, little or no light would enter the examined eye; and it is therefore necessary, when examining an eye with a small or undilated pupil, to use a mirror of very small aperture, so that there may be around this aperture a reflecting zone of sufficient width for the purpose of affording the necessary illumination. For use with an undilated pupil, the mirror aperture should not much exceed one millimetre in diameter, and such an aperture will in most cases render the use of dilating agents unnecessary. On the other hand, when looking into an eye with dilated pupil, a mirror of very small aperture will frequently transmit into the pupil more light than is required, and such excess, as a matter of practical experience, rather tends to obscure fine details by its glare. For the dilated pupil, therefore, it is desirable to have a mirror of smaller illuminating power, that is, of larger central aperture: one of about four millimetres being of a convenient diameter. Loring's ophthalmoscope is provided with the two tilting mirrors required, and they can be exchanged in a moment; the circular metal plates on which they are mounted fitting into the circular spring clip. These mirrors are concave, and of about eight inches focal length; and, with the two discs of lenses already described, they render the instrument complete for the employment of the direct method.

When the indirect method is required, the inverted image is produced, as already described, by the interposition of a convex lens; and for this purpose two such lenses are provided, one of two inches focal length and the other of three inches. The stronger lens gives an image which is small, but brightly illuminated, the weaker lens one which is larger, but less illuminated. Either image may be enlarged for the observer by placing a convex lens behind the mirror.

The relative advantages of the two methods are that the indirect gives a more general view of the background of the eye, a view, that is, which includes a larger portion of the surface, and this under an enlargement which, independently of a magnifying lens behind the mirror, does not exceed about six diameters. The direct method, on the other hand, affords a view of a smaller portion of the surface, but under an enlargement of about thirteen diameters. In the earlier days of ophthalmoscopy, it was a constant practice first to survey the eye-ground by the indirect method, and only to use the direct for any part of it which might seem to call for more complete examination. The tendency of late years, however, has been to use the direct method more and more, and to reserve the indirect for more occasional uses.

Among the occasional uses referred to, are cases in which the vitreous body is turbid, and in which the smaller amount of light required for the direct method is insufficient to penetrate the obscurity. Valuable information may be gained, in such cases, by employing the indirect method with a mirror of deep concavity, which pours a flood of light through the dilated pupil. For this purpose the Loring-Noyes instrument is provided with a deeply concave circular mirror, of about six inches focal length, which also fits the spring clip C. A similar mirror, almost flat, is provided for the determination of refraction by the "shadow test," a full description of which will be found in chapter xiii., pages 435 to 445.

We may now return to the point from which we have digressed, and may assume that it is desired to employ the ophthalmoscope for the examination of an eye. For this purpose, the patient should be comfortably seated, in an otherwise dark or dimly-lighted chamber, and a sufficient flame should be placed on a level with his eye, about a foot from the side of his head, and so far back that no direct light can fall upon the surface of the cornea. The examiner stands or sits opposite to and facing the patient, and the examination should be conducted methodically, beginning with the superficial and extending to the deeper parts of the organ. Let it be assumed that the left eye of the patient is the one to be examined. The character of the flame employed is not of much importance, but a gas bracket with an argand burner is the most convenient; and, in the consulting room, this bracket may be so arranged as to admit of all necessary movements, and of being placed on either side of the patient without changing his position.

The first thing which the observer has to learn is that in the direct method he should always use his own right eye for examining the right eye of the patient, and his left eye for the left eye of the patient. The effect of this is that the two faces almost pass one another, so to speak, and that the observed and the observing eye can be brought into very close apposition, without any contact between the two faces, or any unpleasantness from the breath.

Assuming the left eye to be the one under examination, the observer places the mirror to his own left eye, so that he can see through the aperture. He first tilts the mirror towards his right, and turns the posterior disc two notches to the right, so as to bring a convex lens of sixteen dioptres before the aperture. He then approaches the patient, and keeping the axis of the mirror vertical, he slightly rotates the handle until the light falls full upon the eye. He then approaches still nearer, until the lens gives him a magnified view of the surface of the cornea, which will be brilliantly illuminated. In health it should be transparent, allowing the iris to be seen through it, and should present a central aperture, the pupil, which will shine with a reddish or orange coloured glow. If the pupil is not dilated, the effect of the light will be to produce some contraction, possibly to such an extent as to interfere with the examination; but this contraction may be diminished by directing the patient to turn his gaze somewhat to his right, and to look as if at an object in this direction on the other side of the room. In this position of the eye the light will fall chiefly upon the blind surface of the optic disc; and on account of the distance of the object of vision there will be no tendency to contraction from accommodation.

The only discovery likely to be made in the cornea by the described method of examination is the presence of the remains of fine vessels, left behind by previous keratitis, as causes of slight general turbidity. Such will often be visible, as delicate arborescent lines crossing the general field of illumination. Other and coarser forms of corneal opacity would, of course, have been detected by the preliminary inspection.

Assuming the cornea to be clear, the illumination of the pupillary area may nevertheless be broken by opacities more deeply seated; that is, either in the lens or in the vitreous body. Opacities in the lens are usually either circular and sharply defined, as in some forms of cataract, or stellate, as in other forms. They are stationary when the eye itself is at rest, and, when it moves, they make a considerable excursion in the same direction as its movement, the more considerable, the more superficial they are. It will be manifest that this must be so if we reflect that all movements of the eyeball are rotations upon its centre, so that any object in front of the centre must move in the same direction as the movement, and any object posterior to the centre in a reverse direction. Moreover, as the centre itself remains stationary, the nearer any object is to that centre the smaller will be the amount of its movement. Hence a deposit of lymph on the surface of the anterior capsule of the lens, or a spot or line of opacity in the anterior portion of the lens, will move much farther than a spot of opacity in the deeper parts of the lens, and the precise position or depth within the eye of any opacity may, after a little practice, be very readily estimated.

The same method of examination frequently reveals opacities in the vitreous body, which may be either flocculi or blood clots. These, generally speaking, are movable, so that, even when the eye is at rest, they may be seen to float about; and when they are posterior to the equator, their movements in connection with those of the eye will, in accordance with the principle above laid down, be in a direction opposite to that of the eye movement itself.

In such an examination of the media, when the mirror of the ophthalmoscope is at a greater distance from the examined eye than the focal length of the lens behind the mirror, opacities are only visible as objects which intercept the return of light from the fundus, and hence they appear of an uniform blackness; but if they are in the focus of a powerful lens, and if the illumination be sufficient, they may be seen in the actual colour of their surfaces. Thus, with the convex lens of sixteen dioptres behind the mirror, and with a good light, we may see deposits upon the lens capsule as brown dots, striæ in the lens as whitish lines, and even the redness of coagula in the vitreous. For this purpose, however, the mirror must be brought close to the patient, and the anterior surface of the opacity must be accurately in the focus of the lens.

The examination of the media being concluded, the observer proceeds to the background of the eye. For this purpose he rotates the posterior disc two notches to the left, so as to bring its empty aperture behind the aperture of the mirror, and approximates his own eye as closely as possible to that of the patient. If the latter be emmetropic, the observer will at once see details of the fundus, that is to say, a background of darker or lighter red, traversed by clearly defined blood-vessels. When the eye of the patient is directed a little upwards and towards its nasal side, the entrance of the optic nerve will be exactly opposite the pupil, and will be a conspicuous object of vision when the observer looks directly backwards. If the disc outlines, or the outlines of vessels, although seen, are not seen clearly, the want of definition may be due either to general cloudiness of some portion of the intervening media, or to myopia or hypermetropia on the part of the patient. In order to discover and neutralise the latter conditions, the observer turns the anterior disc a notch to the right, thus bringing a convex lens of one dioptre before the aperture. If this affords an improved definition, but not perfect clearness, he continues to turn the disc to the right until he finds the lens which satisfies all requirements, at once giving a perfect view, and measuring the error of refraction which it corrects. If, on the other hand, the convex lens of one dioptre diminishes the clearness, the disc must be turned the other way, and successive concaves tried until the degree of myopia is arrived at. It will sometimes happen that no lens will afford equally clear definition of all the vessels, but that vessels which course in one direction will be seen best with one, and vessels at right angles to the former with another. Such a condition reveals the presence of astigmatism, and will render it necessary to insert a cylindrical lens of the proper power in the clip behind the mirror, before a perfect view of the fundus as a whole will be obtained.

In the examination of the right eye the steps are the same as those already described, but the lamp must be on the right-hand side of the patient, and the right eye of the observer should be employed. It is obvious also that the tilting mirror must be inclined towards the left of the observer.

During the whole of the above described manœuvres, the handle of the ophthalmoscope and the axis of the tilting mirror should be kept vertical, and the discs of lenses should be at right angles to the axis of vision of the spectator. If the tilting of the mirror does not throw light into the eye of the patient, the position of the lamp must be altered until it does. The knob at the lower part of the handle of the ophthalmoscope rests in the palm of the hand of the observer, so that the instrument is firmly held, and the necessary rotations of the discs are effected by the tip of the index finger. The examination should be commenced and completed without any change in the position of the instrument. The observer may be either seated opposite to the patient or may stand (I prefer the latter position), but should keep his face straight, his left cheek just missing the left cheek of the patient in the examination of the left eye, his right cheek just missing the right cheek of the patient in the examination of the right eye. Beginners may sometimes be seen endeavouring to obtain a view of the interior of the eye by various contortions, twisting their heads and faces into all manner of possible and impossible positions in the hope of at last getting the light into the interior. It is exceedingly important to begin correctly, and to realise from the very first that an invariable position should be assumed. It is frequently desirable to look somewhat obliquely through the sight hole, but this should be done only for a definite purpose, and not in a vague hope of improving the illumination.

In order to use the indirect method, or the inverted ophthalmoscopic image, the arrangement of the lamp and of the patient must be the same as for the direct, but the distance between the patient and the observer is increased. If the *left* eye is the one to be examined, the observer places the mirror before either of his own eyes with his *left* hand, and illuminates the pupil of the patient, keeping the two eyes in line. When the pupil is seen shining with a reddish glow, the observer takes a convex lens, usually of 2 inches focal length, in his *right* hand, between the fore-finger and thumb, and holds it 2 inches, or its own focal length, from the cornea of the patient, obtaining perfect steadiness by resting the tip of his third finger against the upper margin of the patient's orbit. In examining the *right* eye, it is equally immaterial which eye is employed by the observer for the indirect method; but he should take the mirror in his *right* hand, leaving his *left* hand free to manage the lens. In this way the lens is always brought up from the temporal side of the patient, whose nose will not then be in the way, and who cannot breathe over the hand, or up the sleeve, of the examiner. The lens will form an inverted image of the fundus of the examined eye, and will form it about its own focal length from the lens on the side of the observer, so that, with a lens of the power supposed, the image will be 4 inches from the patient's cornea. Such an image will be clearly visible to the observer when he is at a proper visual distance from it, and when his eye, and the eye of the patient, are so placed that their respective visual axes would be coincident if prolonged. If the observer is too near, the image will be ill-defined; if he be too distant it will lose in brightness of illumination. If the observer moves his head much towards either side he will lose the image entirely; and the first principle of the indirect method is that the eye of the observer must be moved to and fro, but never laterally, until the right distance, which implies also correct definition, is obtained. If we may assume that 14 inches is the best visual distance for the observer, and that the image is 4 inches from the cornea of the patient, it is manifest that the two eyes must be 18 inches apart. A larger inverted image may be obtained by the employment of a weaker lens, but one of 3 inches focal length is about the limit which can be employed in the hand. In the first place, if the lens be more than 3 inches from the eye of the patient, the hand which holds it can no longer be supported by resting the third finger against the orbit, and it will be liable to be unsteady, and to impair the definition of what is seen. With a lens of 3 inches, moreover, the image will be 6 inches from the cornea, and an observer with a visual distance of 14 inches will require his eye to be 20 inches from that of the patient. It is manifest, however, that every inch of distance will diminish the amount of light from the mirror which can enter the pupil of the examined eye; and, when the image is large, the light which forms it is distributed over a comparatively large surface, and will appear comparatively faint to the spectator. When the pupil of the examined eye is fully dilated, so as to admit an abundance of light, excellent results may be obtained with a 3 inch lens; but with a moderately small pupil a 2-inch lens is the most useful. With this it is still possible to obtain a great degree of enlargement, coupled with an increase of illumination, by placing a convex lens behind the mirror, and thus at once magnifying the image, and shortening the visual distance so as to bring the mirror nearer to the examined eye. Excellent results may be obtained by using a 2-inch lens to form the image, and by placing a lens of seven dioptres behind the mirror. The observer will then be able to approach to within 6 inches of the image, or 11 inches from the examined eye.

If the inverting lens be held too near the eye of the patient, a portion of the iris of the latter will be visible, and the inverted image will be manifestly encircled and bounded by the margin of the pupil. When the lens is in the right position the pupillary margin disappears, and the image appears to cover, and, as it were, to be painted upon, the whole of the surface of the lens by which it is produced.

When the eye of the patient is hypermetropic, the image will be farther from the lens than its focal length, and will be proportionately larger, with a corresponding diminution in the extent of the field surveyed. When the eye of the patient is myopic, the image will be nearer to the lens than its focal length, and hence brighter than in a hypermetropic eye. The details will appear smaller than usual (for instance, the optic disc will appear small), but the field of view will be comparatively large. In other words, when the optic disc appears to be small, and a large zone of the fundus can be seen around it, the eye is myopic; and, when the optic disc appears large, and occupies most of the field of view, the eye is hypermetropic. It is necessary to bear in mind that, with similar lenses, the apparent size of objects on the background of the eye is entirely governed by the state of the refraction.

For many purposes of optical calculation, a myopic eye may be regarded as an eye plus a convex lens, and this applies to the production of the inverted ophthalmoscopic image. An eye myopic to the extent of ten dioptres would have its far point at 4 inches from the cornea, and, without the interposition of an inverting lens, an inverted image of its fundus would be formed at this point. In cases of high myopia, therefore, an inverted image can be seen without a lens, that is, by the mirror alone, or by the direct method. It would be possible for a beginner to mistake such an image for an erect one, and it is therefore necessary to bear in mind the characters by which the inverted image may be distinguished almost at a glance. One of these is that it appears to move in a contrary direction to any movement of the head of either the patient or the observer, while the erect image moves in the same direction as the actual movement. A still better one is founded upon the anatomy of the optic nerve and vessels. The nerve enters the eye on the nasal side of the posterior pole, and the vessels sweep in bold curves outwards, or towards the temporal side, curves which enclose the region of the macula lutea. When the principal vessels course in this direction the image is erect; and when they appear to pass towards the nasal side of the eye under examination the image is inverted. The inversion is such as would be produced by turning a drawing of the fundus upside down. The upper margin appears to be the lower, the right side to be the left, and *vice versa.*

Beginners frequently experience some difficulty, in the examination of the inverted image, from the interruption to vision which is occasioned by inverted images of the flame reflected from the surface of the cornea of the examined eye, and from the two surfaces of the inverting lens. The corneal reflection may be removed by slight movement of the eye itself or of the mirror; and the lenticular images by giving to the lens a slight amount of obliquity by rotation upon either its vertical or its horizontal axis. When this is done the flame images move apart from one another, and the retinal image is no longer obscured by them. The reflected image of the mirror itself is also a possible source of embarrassment, and it is said that the image of the central perforation has even been mistaken for that of the optic disc. All difficulties of this kind may be obviated by a slight change, either of the angle of the mirror, the eye of the patient or of the observer, or of the position of the flame.

It has already been mentioned that in high degrees of myopia, and for practical purposes such degrees must amount to ten dioptres or more, an actual inverted image of the background of the eye can be obtained by the direct method, that is, by the mirror alone, without the interposition of a convex lens. The inverted image, in such cases, is formed in the plane of the far-point of the examined eye; and hence its distance from the cornea of the patient affords a measure of the actual degree of his myopia. This distance is easily ascertained by an observer who knows his own visual distance, or who can fix this by placing a convex lens behind his mirror. My Loring-Noyes ophthalmoscope is furnished with a small clip N (Fig. 6), to which the metal case of a spring tape measure can be attached. Placing a lens of + 5·0 behind the mirror, so as to bring my own visual distance to eight inches, the focal length of this lens, I get the inverted image into perfect definition, and then, by drawing out the tape, measure the distance between my own eye and that of the patient. Deducting eight inches for my own visual distance, the remainder expresses the distance of the inverted image from his cornea, and hence the degree of his short-sight.

The appearances seen with the ophthalmoscope, and the methods of interpreting them, will be dealt with under the diseases to which they respectively belong, but it is worth while to state in this place certain facts which are generally applicable to all examinations.

The degree of enlargement of the inverted image has already been said to be greater when produced by a weaker lens, but it is also governed by the refraction of the examined eye. It has, practically, two factors, one of which is the focal length of the inverting lens, while the other is the distance between the retina and the nodal point of the examined eye. In the emmetropic eye, this distance is about 16·6 millimetres, being, of course, greater in myopic eyes and smaller in hypermetropic. The enlargement is arrived at by dividing the former quantity by the latter, so that, with a lens of two inches, or 54 millimetres, the enlargement would be equal to 54 divided by 16·6, or roughly, to three diameters and a third. In the same way, with a lens of three inches, or 81 millimetres, it would be five diameters. As the divisor increases in magnitude, as in myopia, the enlargement would diminish, while, as the divisor diminishes, as in hypermetropia, the enlargement would increase. In hypermetropia of ten dioptres the distance from the nodal point to the retina is about twelve millimetres, in myopia of ten dioptres it is about eighteen millimetres; so that, in the former instance, the enlargement would be 81 by 12, or seven diameters, while in the latter it would be 81 by 18, or four and a half diameters. These calculations are based upon a visual distance of eight inches for the observer, which, in a presbyopic person, can only be obtained by placing a convex lens behind the mirror. If a still stronger lens be thus employed, as already advised when a large image is required, the result is obtained by dividing the former visual distance by the nearer one obtained, and by multiplying the previously calculated enlargement by the quotient.

Thus, if a lens of six-inch focus be placed behind the mirror, the enlargement effected by it will be equal to 8 by 6, or 4 by 3, by which the previously calculated enlargement must be multiplied. In this way an enlargement of some nine diameters may be attained, but the limit is reached at this point, on account of the narrowing of the field of vision. As a compensation, we obtain, in the use of the inverted image, a larger field of vision than with the erect. The magnitude of the field is best expressed in terms of the diameters of the optic disc, and would theoretically amount to three such diameters with a two-inch lens, and five with a three-inch. In practice, the theoretical extent is seldom quite attained, on account of further lateral limitations imposed by the shape of the flame. The extent and the enlargement stand in an inverse ratio to one another, so that it is often well to begin the examination with a lens of short focal length, so as to obtain the largest possible extent of view, and to proceed to greater enlargement, first by using a weaker lens for the inverted image, and finally by the direct method.

Assuming the mirror to be from twenty to twenty-four inches from the flame, the best illumination of the inverted image is afforded by a concave mirror of about six inches focal length. It is always desirable to possess such a mirror, more especially for cases rendered difficult by turbidity of the media, a condition which abundance of light may enable the observer to penetrate.

The enlargement of the erect image, which is not an actual but a virtual image, or the background of the eye seen magnified by its own crystalline lens, amounts to about fourteen diameters in an emmetropic eye. In a hypermetropia of thirteen dioptres the enlargement would not exceed ten diameters; while in a myopia of thirteen dioptres it would amount to nearly eighteen diameters. The general result is, therefore. that the erect image is more magnified in myopia of the patient than in emmetropia; and more magnified in emmetropia of the patient, than in hypermetropia, and that the reverse is true of the inverted image.

The field of vision in the erect image has already been said to be smaller than in the inverted, and seldom exceeds two diameters of the optic disc. In order to extend it as much as possible, the observer must bring his eye very close to that of the patient, and the pupil should be fairly well dilated. It is therefore desirable to use a plane or very slightly concave mirror, so as not to cause contraction of the pupil by an undue amount of illumination. Artificial dilatation may be employed by beginners, but it will only be required in exceptional cases by a skilled observer.

I have assumed so far, in speaking of both methods of examination, of the direct as well as of the indirect, that the eye of the observer is passive and emmetropic, but there must manifestly be numerous instances in which this assumption is not fulfilled, and in which the observer is either hypermetropic or myopic. In the inverted image these conditions make but little difference. The myopic observer approaches nearer to the image than the emmetrope, and sees it under a somewhat greater enlargement; the hypermetrope keeps somewhat farther away, or obtains the ordinary degree of approximation by the aid of a convex lens behind the mirror. In the erect image, however, the lens employed in the latter position must be sufficient to correct the ametropia of the observer as well as that of the patient, and the former being always a known quantity, the correction presents no difficulty. An observer with four dioptres of myopia requires, let us say, a correcting concave of eight dioptres in examining a particular patient. Of this correction, four dioptres being required for himself, only four are left as the measure of the myopia of the patient. If the same observer saw the details of an eyeground without any lens being interposed, the patient would have a hypermetropia of four dioptres, which would exactly neutralise the myopia of the observer. The necessary addition or subtraction can always be made in an instant, and the ametropic observer may generally save time by beginning with his own correcting lens behind the mirror. He will then pursue precisely the same course as if he were emmetropic, and will only have to make the required allowance for his own defect when his examination is completed.

The manner of roughly testing the lateral extent of a patient's field of vision has already been described, but it will sometimes happen that the ophthalmoscope affords reason for conducting such an examination in a more accurate and systematic manner. In the normal condition the field of vision of each eye singly extends over about 120 degrees from above downwards, and over about 160 degrees from side to side, the vision being most acute at the centre, where the image falls upon the yellow spot, and progressively diminishing in acuteness to the periphery. Colour vision is less acute towards the periphery than vision of form, a white object being seen at a greater distance from the centre than a red, and a red than a green. The defects commonly met with in the fields are either concentric narrowing, irregular narrowing, the loss of one-half, or of some considerable sector, or the presence of blind or dimly sighted spots or patches, called scotomata, which may be either central or lateral. The earliest attempts at testing the state of the field were made by means of a very primitive apparatus, consisting simply of a black board, on which a small central cross was marked as an object of vision. The patient was placed with the eye to be examined opposite the little cross, and twelve inches distant from it, the other eye being covered, and was directed to fix his gaze upon the cross without allowing it to stray in any lateral direction. The examiner then took a blackened rod, provided with a small white knob at one extremity, and drew this knob slowly across the board from the margin towards the centre, until it entered the field of vision and was seen by the patient. As soon as the patient saw it he was directed to speak, and a chalk mark was placed on the board at the spot which the white knob had reached. This process was repeated until the white knob had been moved from circumference to centre along, not only the horizontal and vertical meridians, but along as many intermediate meridians as the case might seem to require, and ultimately all the marks were united by a line which exhibited the boundary of the field. In many cases, after marking on each meridian the spot at which the white knob first came into view, it was the practice to move it still farther towards the centre, until it reached a point at which it could be seen clearly, and to unite the inner series of marks as well as the outer series, thus obtaining an outer line which gave the boundary of actual vision, and an inner line which gave the boundary of distinct vision. The great difficulty of carrying out the process above described, was that the examiner could not so place himself as to watch the movements of the eye under inspection, and this had a tendency to wander towards the moving object, which was therefore often said to be visible before it would have come into view if central fixation had been maintained. Professor Donders attempted to overcome this difficulty by making a central perforation in the board, and by directing the patient to look through this central perforation at the eye of an assistant on the other side, whose duty it was to give notice if the eye, which was being tested, wandered away from his. A minor defect in the process arose from the flatness of the board, which caused its lateral parts to be farther from the eye than the centre; and it was not until the invention of Professor's Förster's perimeter that these difficulties were even partially overcome. Subsequent contrivers have endeavoured to improve Förster's perimeter, which is now seldom used; and the best instruments now appear to me to be that of Mr. Priestley Smith, and one for which I must myself take the responsibility. It will be sufficient if I describe the latter.

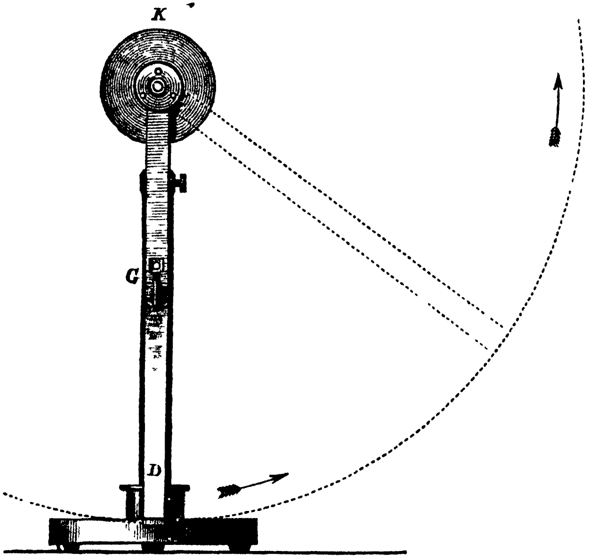

Fig. 10.—Perimeter.

My perimeter is shown in front view in Fig. 10, and in profile in Fig. 11. It consists of a heavy metal foot A, from which rises a double telescopic stem B, so that the centre of the instrument can be set at any desired height, and retained by the screw C. From the centre projects a quadrant D, curved on a radius of

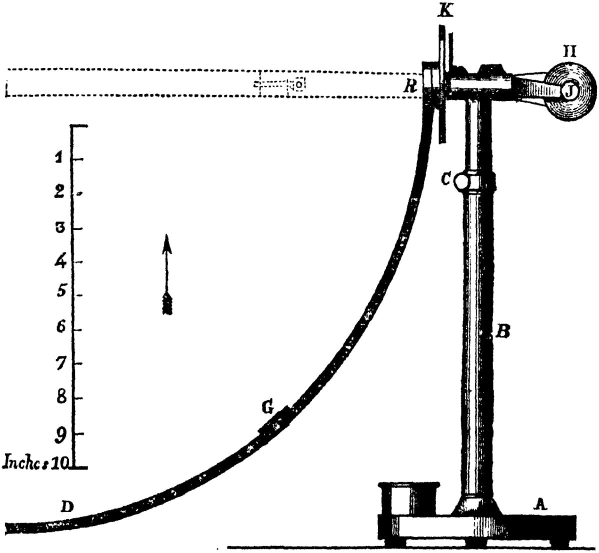

Fig. 11.—Perimeter.

twelve inches, and formed of metal tube, which is quadrangular in section. This quadrant turns upon a central pivot, so that it can be made to describe a complete circle, and can therefore be placed in any desired meridian. Its pivot presents a flat surface, on which a white spot is painted as a fixing object. A small carrier G runs along the quadrant, and is moved by a fine but strong thread, carried round the wheel H, which is governed by the milled head

J. By turning this milled head right or left, the carrier can be made to traverse the quadrant rapidly in either direction, from periphery to centre, or from centre to periphery. The carrier is ordinarily furnished with a white spot as an object, but a red or green one can be substituted whenever desired. The quadrant is marked in degrees from centre to circumference, and the pivot is provided with a disc K similarly marked, so as to denote the meridian in which the examination is being conducted. A record of the observations is made upon a circular chart, divided by concentric circles into zones indicated by degrees, and by radiating lines or meridians into sectors.

In conducting the examination, the patient is seated opposite the instrument, with his chin supported by a simple telescopic chin rest, set at such a height that the plane of the face is vertical. There should be a full light on the concavity of the quadrant, but the face of the patient must not be too much in shadow, as it is necessary that the movements of his eye should be watched. The centre of the perimeter is set at the same height as the eye of the patient, and twelve inches distant from it; and the patient may rest the elbow of the side not under examination on the table, and may cover the eye on that side with his hand, a position which ensures steadiness. When all is arranged the patient is directed to look steadily at the central white spot, and the examiner, standing behind the instrument, is able to see whether this direction is strictly obeyed. It is best to have a systematic manner of proceeding, and my own practice is to commence with the quadrant vertically downwards, and to bring in the travelling spot from the periphery towards the centre until its presence is seen. As soon as this occurs a pencil or ink mark should be made on the corresponding point of the chart, and the traveller may then, if necessary, be moved over the rest of the meridian, so as to determine the limit of clear vision, and also the presence or absence of any gap in the field. The examination of that meridian being completed, the quadrant may be raised towards the temporal side of the eye under inspection. In many cases it will be sufficient to take the horizontal and vertical meridians simply, and the intermediate ones only in cases in which the former show some defect, or in which the ophthalmoscope shows patches of retinal disease which are likely to occasion blind spots. It is manifest that the construction of the instrument allows the examination to be repeated in as many meridians as may be desired, so that the precise boundaries of any defect can be traced and recorded, and thus preserved for comparison with future conditions of the case. It must never be forgotten, however, that the accuracy of perimetry is dependent on the trustworthiness of the patient, and that, even for intelligent people, it is often extremely difficult to keep the eye from wandering in a manner which will vitiate the results. Not only, therefore, must the eye be most carefully watched by the examiner, but no strange or unexpected result should be accepted until it has been verified by more than a single observation. A fair test of the patient's own accuracy is afforded by the blind spot at the entrance of the optic nerve. When the eye is steadily directed to the central fixing point, the blind spot in the field is on the temporal side, a little below the horizontal meridian; and, at twelve inches, will cover an elliptical space about one inch in height, and about three-fourths of an inch in breadth. If the patient sees the moving spot in this region, where he would not see it if central fixation were properly maintained, his other statements can only be received with a certain amount of reservation.

The diagram in Fig. 12 gives a chart of the field of vision of my own left eye, for white, red, and green, taken at twelve inches on a moderately bright spring day in London.*

It will still be necessary, in certain cases, to examine into the state of colour vision; for information on this subject the reader may be referred to chapter xi., in which it is fully dealt with.

The last point in the systematic examination to which attention should be directed is the tension or hardness of the eyeball, which is determined by careful palpation; and, as this palpation may itself modify the state of vision, it is best to defer its employment until all other questions have been decided. In order to estimate tension, the patient is directed to close the eyes gently, and to look down, and the surgeon then places the tips of his two fore-fingers upon the upper lid, and insinuates them a little under the margin of the orbit, so that they rest almost upon the equator of the eye. One finger is then used to support and steady the globe, while the other gently presses it, and feels the degree of resistance which is offered to the pressure. This resistance, in a healthy eye, is such as to give a sense of elasticity to the finger, and to allow a certain amount of dimpling of the ocular tunics; but, in morbid states, the eyeball may be found either unnaturally soft or unnaturally hard, or in more technical phraseology, to be in a state of either

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* A reviewer of the first edition of this book says: "Mr. Carter falls into the very common error of describing the field of vision for green to be smaller than that for red, without stating the hue and shade of each colour used in testing. As a matter of fact, when the colours are complementary the limits are the same!" It is perhaps worth while to answer this amazing piece of criticism by pointing out that the resources of language do not extend to an accurate description of the "hue and shade" of colour; and that "red" and "green" cannot be complementary in any circumstances. The complement to red is a mixture of green and blue; the complement to green is a mixture of red and blue. R. B. C.

plus or *minus* tension. Unless the eye is carefully steadied before the pressure is commenced, it may appear soft simply from being pushed back into the orbit, more especially when, as often happens in elderly people, the orbital fat has in a great measure been removed by absorption. By attention to the simple directions above given, any error of this kind can be avoided; and the surgeon will always carry about with him, in his own eyes, standards with which the tension of the eyes of the patient may be compared. It is also very important to compare the two eyes of the patient with each other; because, although there

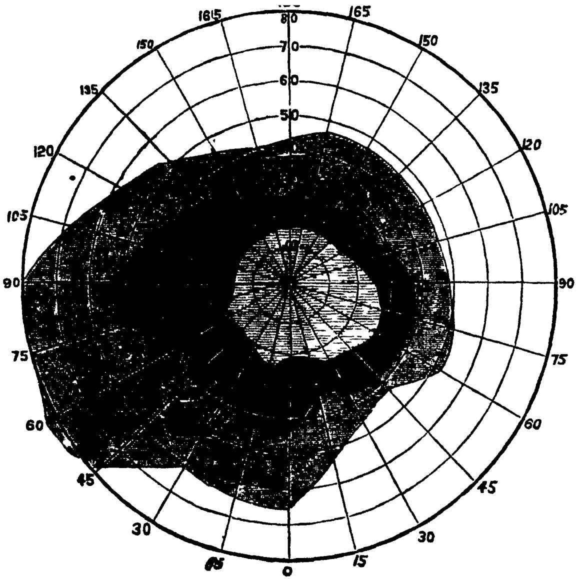

Fig. 12.—Chart of a Field of Vision.

is a certain amount of physiological variation of tension, within limits which it would not be easy to define, it is very rare to find differences of tension between the two eyes of the same person except as a consequence of disease. The subject will be again noticed in the chapter on glaucoma, that being the malady in which varieties of tension assume the highest importance as aids to diagnosis and as indications for treatment. Tension is expressed in note-taking by a capital T, preceded by a *plus* or *minus* sign, and followed by a numeral expressive of degree. Thus + T 1 expresses distinct hardening, + T 2 decided hardening, and + T 3 extreme hardening, so that no dimpling can be produced. T *n* signifies that the tension is normal, and the *minus* sign is used, in contradistinction to the *plus* sign, as a prefix to three degrees of softening.

R. B. C.

CHAPTER III.

AFFECTIONS OF THE EYELIDS, LACRYMAL APPARATUS, AND CONJUNCTIVA.

THE eyelids serve the double purpose of protecting the eyes, and of lubricating their surfaces. For the proper exercise of their functions it is essential that their movements should be free, their curvature approximately the same as that of the globe, their edges fringed with cilia, and their mucous surface smooth. The tissues which enter into their formation are continuous with those of contiguous parts, but are much modified to give the necessary lightness and mobility. Thus the skin is extremely thin, and contains only a few very minute sweat glands, and as a rule no hairs except at the margin, the meshes of the subcutaneous cellular tissue contain no fat, and the necessary rigidity is given by a condensed layer of white fibrous tissue beneath this, the so-called tarsal cartilage or tarsus. Partly embedded in the latter, and partly lying on its conjunctival surface, are the meibomian glands, which, twenty to thirty in number, run vertically down to the margin of the lid, where they open by minute orifices behind the eyelashes. The lids are lined by a layer of mucous membrane, which adheres intimately to the tarsus, its surface is finely vascular, and appears to the naked eye to be perfectly smooth, but viewed with a lens is seen to be covered with exceedingly minute papillæ. At the margin of the lids the mucous membrane is continuous with the lining of the hair follicles and meibomian ducts, and with the skin. After lining the lids it is reflected on the globe, forming at its point of reflection a deep cul-de-sac beneath the upper, and a more shallow one beneath the lower lid. The lids are connected with the margin of the orbit by a thin membrane and by small ligamentous bands at either extremity; the latter cause the upper lid in rising and falling to describe a partial revolution round an imaginary line connecting its extremities, like the visor of a helmet.

The upper lid is moved by two muscles, the orbicularis, which forms a flat layer in the loose subcutaneous cellular tissue, and the levator palpebræ, which, coming from the apex of the orbit, spreads out fan-wise, and forms an aponeurosis which is connected with the upper border of the tarsus. The orbicularis, which is supplied by the facial nerve, by its tonic contraction keeps the lower lid from falling away from the globe by its own weight; by its moderate contraction the eyelids are closed; when it contracts forcibly the skin is thrown into wrinkles, and the globe is pressed upon. The elevator is supplied by the third nerve. In addition to these voluntary muscles there is a layer of unstriated muscle, called after its discoverer Müller, which passes back into the orbit, and is connected with an offshoot from Tenon's capsule. It is supplied by the sympathetic, and by its action causes retraction of the lids, widening of the palpebral fissure, and sometimes prominence of the eyeball.

At the margin of the lids are the openings of the hair follicles from which protrude the lashes, while farther back, and also opening on the free edge, are the orifices of the meibomian glands.

Near the inner extremities of both lids the lashes and meibomian glands are absent, and the substance of each lid is traversed by the canaliculus *b b* (Fig. 13), which terminates a quarter of an inch from the inner canthus in an opening, the punctum lacrymale, *a a*, at the summit of a papilla. At their inner extremities the canaliculi open into the lacrymal sac *c*, which lies in a bony depression, but in front is covered only by soft parts, below it is continued as the nasal

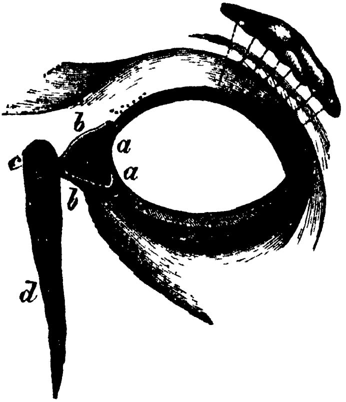

Fig. 13.—Lacrymal Apparatus.

duct *d*, which opens immediately below the inferior turbinated bone.

AFFECTIONS OF THE EYELIDS.

Only such affections of the skin as present peculiar features in consequence of their situation will be considered here.

Herpes, occurring in the course of the first division of the fifth nerve, is often extremely intractable, and is not unfrequently accompanied by ulceration of the cornea, which may lead to perforation and total loss of the eye. The cornea, it is said, is more frequently involved when the nasal branch of the nerve is affected, but this is not essential. When the rash has disappeared, which it generally does in about a fortnight, the cutaneous scars often remain excessively painful and tender for a very long period. An

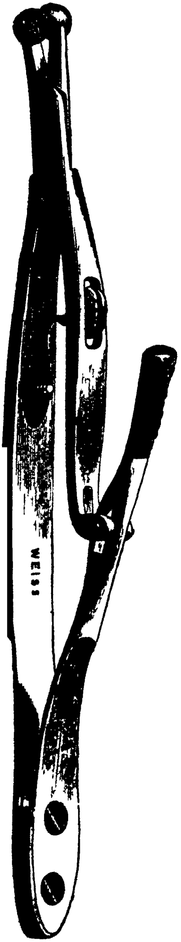

Fig. 14.—Noyes's Needleholder.

error is often made in diagnosing herpes frontalis as erysipelas; but the small size of the vesicles, their distribution along the course of a nerve, and the great pain, should render the nature of the case obvious. The affection is believed to be due to interstitial changes in the casserian ganglion, whose existence has been proved in one instance; if this is the case a prolonged mercurial course might be useful. Nervine tonics, as arsenic and quinine, are also indicated. Locally the pain may sometimes be relieved by the subcutaneous injection of cocaine, or by the continuous current. When there is localised tenderness over the point of exit of the supra-orbital nerve, the latter may be divided; the relief, however, is generally only temporary, and although excision of a portion of the nerve is more likely permanently to remove the pain, even this sometimes fails.

Molluscum contagiosum, as it occurs upon the eyelids, presents a characteristic appearance which can hardly be mistaken. Along the free margin of the lids are several hemispherical swellings, the largest usually about 3 mm. in diameter; their surface is white, and presents a small central depression. Occasionally they occur on the lid at a distance from the margin. The treatment consists in transfixing them and squeezing out their contents, which are the same as those of an ordinary sebaceous cyst.

Translucent cysts of small size occasionally occur on the eyelids, from distension of the minute sweat glands; they never attain a large size, and are readily removed by puncture.

The other superficial affections of the eyelids do not differ essentially either in the symptoms they present, or in the treatment they require, from similar affections of other parts. It must, however, be borne in mind, that in the removal of any part by the knife or caustic, cicatricial contraction must be guarded against as far as possible, and, when unavoidable, care must be taken that it acts in such a direction as to cause the least interference with the normal position and movement of the lids.

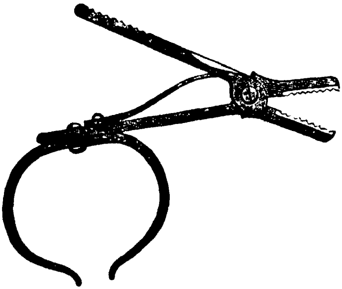

Fig. 15.—Weiss's Needleholder.

Owing to the great mobility of the integument, it is difficult even with the sharpest scalpel to avoid a little jagging of an incision, the latter is therefore better made with scissors, the blunt-pointed blade being passed beneath the skin, through a small puncture. In uniting wounds of the eyelids, fine curved needles, threaded with silk, are useful; these are conveniently held by one of the needle-holders shown in Figs. 14 and 15.

Owing to the absence of fat in the subcutaneous cellular tissue, effusion of any kind very readily takes place into it, hence œdema occurs with any slight local inflammation, and is often seen there first in conditions which give rise to general anasarca. For the same reason, and because the tissues are easily contused against the bony margin of the orbit, considerable ecchymosis follows comparatively slight blows.

Acute cellulitis is generally of an erysipelatous nature, and is not unfrequently secondary to inflammation of the lacrymal sac, but it may occur spontaneously, or as the result of injury. The œdema is always considerable, and the pain severe. Suppuration occurs early, and, when the lid only is affected, the symptoms subside rapidly when the pus has been evacuated. When erysipelas of the face extends to the eyelids, there is the danger that it may spread to the cellular tissue of the orbit; this complication, which is exceedingly serious, will be considered in chapter xv.

A **hordeolum**, or stye, is a localised inflammation of the cellular tissue, and is therefore analogous to a boil in other parts. It usually, but not always, attacks the tissue immediately surrounding one of the cilia. There is usually some œdema of the lid, which may be so considerable as to mask the more localised inflammation; the edge of the lid is swollen and red at one part, from the centre of which one of the eyelashes projects. There is at first a smarting pain, which soon increases, and assumes an aching or throbbing character, the inflamed area increases in extent, and in a few days a small bead of pus makes its appearance on the free edge of the lid. As soon as the pus has escaped the inflammatory symptoms subside, although considerable thickening often remains for a week or two. Sometimes there is permanent loss of a few eyelashes at the part affected. Like boils in other parts, several styes are apt to occur in succession, indicating some defect in the general health, especially habitual constipation, or some local irritation, such as working in a dusty atmosphere, or an uncorrected error of refraction.

If a stye be seen in the earliest stage, its progress can sometimes be arrested by removing the eyelash which it surrounds, and cauterising the follicle with a needle at a red heat. If it has passed this stage, suppuration must be encouraged by hot fomentation, and an incision made as soon as the pus points. Any cause must be removed; when none such can be discovered, sulphide of calcium in doses of half a grain three times a day may be given, the bowels should be kept regular by mild laxatives, the diet regulated, and open air exercise enjoined.

Chalazion (tarsal cyst, or tumour; meibomian cyst), which is one of the most common of the non-inflammatory swellings of the eyelids, is a retention cyst, formed by distension of one of the meibomian glands from blocking of its duct. The accumulated secretion first distends the acini of the gland, and then causes hypertrophy of its wall. In this way is produced a well-defined, rounded swelling of the lid, which does not implicate the skin, and is unaccompanied by inflammatory symptoms. Sometimes it is the duct which is chiefly distended, and then the swelling has an elongated form. Such tumours tend very slowly to increase, but their growth is entirely painless, unless they become inflamed.

The situation of the cyst varies, being sometimes on the conjunctival surface of the tarsus, and sometimes embedded in its substance. The contents also differ much, being sometimes quite fluid, at others, firm and caseous. They consist of sebaceous material, epithelial cells, and fatty substances.

As the cyst increases in size, the conjunctival covering generally shows a bluish discoloration where it is thinned by the pressure. Occasionally suppuration takes place, when the symptoms will resemble those of a stye. If the cyst rupture on the conjunctival surface, the escape of the contents is often followed by the sprouting of granulations from the interior, which spread out, forming a kind of fungoid excrescence.

The treatment consists in everting the eyelid, and incising the cyst with a Beer's cataract knife; the contents are then thoroughly removed with a scoop. The bleeding is generally free, and the cavity becoming filled with blood, the tumour for a few days often looks as large as before, but soon subsides. Some authorities recommend that the lining membrane should be freely lacerated with a needle, but this is unnecessary, although it might be desirable in case of recurrence. A button of granulations sometimes sprouts through the wound; this must be snipped off and its pedicle cauterised. Occasionally, tumours of a similar nature, but small and hard, are met with, which show no thinning of the cartilage in the substance of which they appear to be situated; these are better removed by making an incision in the skin, and dissecting them out.

Fig. 16.—Scoop for Meibomian Cysts.

Tinea tarsi, ophthalmia tarsi, or blepharitis, is one of the commonest affections of the eyelids among the poorer classes. It consists in an eczematous inflammation of the muco-cutaneous surface of the margin of the lid, and usually implicates the hair follicles. It occurs more commonly in children, an attack of measles being often the cause.

The earliest symptoms are slight smarting pain, redness of the edges of the lids, and a glueing of them together in the morning. The lid margins soon become swollen, the swelling extending about a quarter of an inch up the lid, a secretion exudes from the hair follicles, which at first can be seen with a lens forming a thin wrinkled film like a layer of collodion; it soon, however, becomes more abundant, and forms crusts which mat the eyelashes together, at the same time the follicles become distended, and the lashes being thus loosened are only held in by the dried secretion; when they fall out they are replaced by others which are finer, and have often an irregular direction. After several crops of lashes have been shed in this way, the hair follicle becomes destroyed, and they are no longer replaced. In the meantime, the lid has become more and more everted, the exposed conjunctival surface is inflamed, and the eye, from exposure to dust, etc., suffers from frequent attacks of conjunctivitis, in the course of which opacities are often formed on the cornea. The eversion of the lower lid still further aggravates the mischief by carrying the lacrymal punctum away from the globe, so that the tears can no longer enter it, but flow over the cheek, rendering the skin sore.

The treatment consists, in the first place, in carefully removing all coagulated secretion from the openings of the hair follicles; it is important in doing this not to cause bleeding from the surface beneath, the crusts should therefore be first softened by bathing or soaking the lids thoroughly with a warm alkaline lotion (Formula 20, Appendix D). An astringent ointment (Formula 32, Appendix D) should then be rubbed well into the edge of the lid, either with the finger, or with a camel-hair brush cut short. The ointment should, if necessary, be first softened by heat. This should be done at least three times a day, and each time any lashes that are loose should be removed.

When the edge of the lid is much reddened and swollen, it may be painted with a solution of nitrate of silver, of 20 grains to the ounce, or lightly touched with the dilute stick. In severe cases, and when the patient is neglected, it is a good plan either to cut the eye-lashes quite short, or to remove all of them; to do this, each hair should be seized with the epilation forceps and steady traction made; in children an anæsthetic is necessary. In the latest stage little can be done beyond palliating the condition by keeping the lids clean, protecting the eyes from glare and dust by tinted glasses, and slitting up the canaliculus, in order to afford a proper exit for the tears. The worst cases occur among those who are compelled to follow an out-door occupation.

Ptosis, or drooping of the upper lid, occurs when there is paralysis of the levator muscle, and sometimes when weight and size of the lid are increased, as from inflammatory swelling.

Ptosis from partial or complete paralysis of the levator is occasionally seen as a congenital condition, affecting one or both eyes; it varies in degree, but is never complete; very frequently there is also a defect in the power of rotating the globes upwards. In some cases in which there seems to be no power in the elevator muscles, the lids are raised by the action of the occipito-frontalis. Occasionally the ptosis is variable, being at one time considerable, at another hardly noticeable.

The treatment will depend upon the range of movement of the lid; should this be considerable, all that is necessary is to excise a fold of skin, and a corresponding portion of the orbicularis, bringing the edges of the wound together with sutures. This operation may be performed in two ways: (*a*) a horizontal fold of skin may be seized with the forceps shown in Fig. 17 and excised with scissors; or (*b*) one incision may be made along the whole length of the lid just above its edge, and another above this, curved with its concavity downwards, its two extremities meeting those of the first; both are best commenced by a puncture and completed with scissors. The enclosed semilunar portion of skin is then dissected off. This operation takes longer than the first, but renders it more easy to regulate the amount of skin removed. Both operations are painful, but sufficient anæsthesia can be produced by injecting cocaine subcutaneously; as, however, this distends the integument, it is a good precaution to mark out the line of incision first.

When there is no power of raising the lid, the only method available is to bring the occipito frontalis to act more efficiently upon it. This has been done by producing deep cicatrices connecting the lid with the muscle by means of sutures, left in sufficiently long to excite suppuration. Or a plastic operation may be performed, which consists in connecting the integument of the

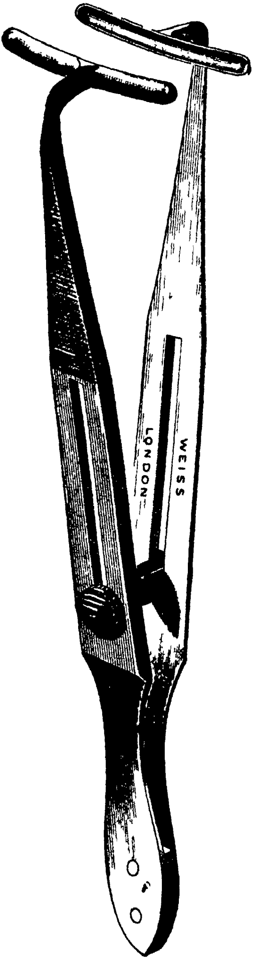

Fig. 17.—Forceps for Excising a Fold of Integument.

upper lid directly with that over the occipito-frontalis, by raising the former as a flap, and passing it beneath the intervening bridge of integument.* Acquired ptosis is usually associated with paralysis of the other muscles supplied by the motor oculi, and its treatment will, therefore, be considered in chapter xiv.

Epicanthus is a congenital malformation in which a semilunar fold of integument stretches across the inner canthus; it is always symmetrical, and is associated with a flat bridge to the nose, which much increases the effect of the deformity. It can be remedied by the operation of canthoplasty; this consists in dividing the fold with a pair of scissors, and then uniting the adjacent cut edges with sutures. Another operation sometimes adopted consists in removing a vertical fold of skin from the bridge of the nose, and bringing the cut edges together, thus dragging the folds inwards.

Congenital narrowing of the palpebral fissure, or atresia palpebrarum, is a rare condition, and is not unfrequently associated with defective development of the globes, in which case nothing can be done. A similar condition also results from the contraction produced by long-continued granular ophthalmia. It may be relieved by canthoplasty.

Coloboma of the eyelid is the term applied to a congenital deficiency in some part of the lid; sometimes it is associated with coloboma of the iris.

Paralysis of the orbicularis prevents the eye being closed, and causes the lower lid to fall somewhat away from the globe, so that the punctum lacrymale is no longer in contact with it, and the tears in consequence do not enter it, but flow over the cheek. The treatment will depend upon the cause; in old-standing cases atony of the muscle should be prevented by galvanism. When the condition is likely to be permanent, the canaliculus should be slit up to rid the patient of the epiphora, or one of the operations for the relief of ectropion may be performed.

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* Panas, *Arch. d'Ophthal.*, Jan. and Feb., 1886.

Blepharospasm, or spasmodic contraction of the orbicularis, is a not unfrequent complication of severe catarrhal ophthalmia in children ; its results and treatment will be considered with that condition. In old people, in whom the integuments of the eyelids are very lax, the contraction of the muscle occasionally rolls the lower eyelid in, so that the lashes either brush against the cornea, or are turned right into the lower cul-de-sac. This spasmodic entropion, or inversion of the lid, is especially liable to follow any slight irritation in old people, such as an operation wound on the eye, a corneal ulcer, etc.

When recent, and following an operation, leaving off the bandage will occasionally effect a cure, especially if the patient will, for a few days, pull the lid out every time it becomes inverted. If this fails, the lid should be pulled well down, and a layer of contractile collodion be painted over it and the adjacent cheek ; this, when properly applied, is very efficacious, the collodion, as it contracts, draws the lid still farther away from the globe, and will keep it so for many days. When the condition has existed a long time, or (*see* page 9) the above methods of treatment have failed, a strip of skin should be excised.

A condition which occasionally causes considerable discomfort and annoyance is a quivering movement of the eyelids ; which comes on at frequent intervals, and without obvious cause, and lasts only a few minutes. It is probably due to loss of tone of the orbicularis muscle, aided by some reflex irritation. All local causes should be sought for and removed, and the patient placed on a tonic regimen, the so-called nervine tonics, such as arsenic and quinine, being especially indicated.

Phthiriasis palpebrarum, the pediculus pubis, occasionally attacks the eyelids, and might perhaps be mistaken by a careless observer for tinea tarsi. There is produced, however, an amount of irritation which is out of proportion to the inflammatory signs, and the little brown ova which can be seen adhering to the lashes are much smaller than the crusts in blepharitis, and do not cause any matting together of the lashes. The treatment consists in epilation of the affected hairs, and the careful use of red precipitate ointment.

Organic entropion is a more troublesome condition, and depends upon an alteration in the form of the lid. The usual cause of this is contraction of the cicatricial material in and beneath the conjunctiva in long-standing granular ophthalmia, a contraction which is sometimes induced or increased by the injudicious applications of caustics. The result of this is that the concavity of the lid is increased, and the lashes brush against the cornea. Since it is this latter condition that irritates the eye, it will be convenient to consider here the conditions in which some of the eyelashes become inverted without there being any change in the shape of the whole lid.

Trichiasis is the name given to the condition in which several lashes are turned in. These may lie at different parts of the lid, or all the hairs over a limited extent of the lid may be affected. These conditions are not unfrequent after prolonged blepharitis, and occasionally follow a stye.

The inverted lashes are a constant source of irritation, and give rise to conjunctivitis, pannus, and ulceration of the cornea.

The treatment must be modified according to the requirements of each case. When only a few lashes are affected, they may be removed as often as they become troublesome, each hair being seized separately close to its root with a pair of forceps, and steady traction made. The patient may be instructed how to perform the operation himself. Sometimes, after the hair has been repeatedly removed, it is no longer reproduced. When the lashes are reproduced after intervals that are inconveniently short, the hair follicle may be destroyed by passing a hot needle, or the cautery shown in Fig. 18, into it as soon as the hair is removed, or by electrolysis. The latter is applied by passing a needle, connected with the negative pole of a battery equivalent to ten Leclanché cells, down the hair follicle, and applying the other pole to the neck. The circuit is completed when the needle has been introduced, and the latter is kept in about ten seconds; the eyelash will then be found to be lying loose in the follicle, and should be removed. Both these proceedings, when many lashes are involved, are extremely painful, and cocaine for the latter is not of much use. In all operations on the eyelids involving the use of the cautery, the eye should be protected by an ivory spatula (Fig. 19). When several adjacent lashes are involved, they may be destroyed by strangulating the tissues in which they lie with a subcutaneous ligature; or the hair bulbs may be excised by making an incision in front and behind them, reaching up into the lid as high as their roots, and removing the included tissue with

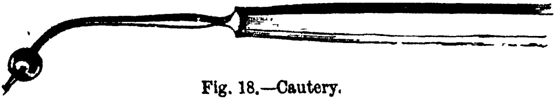

Fig. 18.—Cautery.

sharp scissors, or *snaring* may be employed. A needle threaded with both ends of a hair is entered close to the lash and brought out just above the edge of the lid, the lash is then snared in the loop which is drawn through.

For entropion of the lower lid, excision of a fold of skin is usually sufficient.

When the whole upper lid, or a considerable portion of it, is incurved, some operation must be performed which either alters the shape of the whole lid, or the position of its margin. Of such operations an immense variety have been devised, from which may be inferred the intractability of the affection. Only a few of these will be described in order to indicate the principles upon which they depend.

Fig. 19.—Ivory Spatula.

In the first place, any operation which aims at removing any large proportion of the eyelashes is wrong in principle, and, of course, this applies even more to the barbarous mutilation that used to be practised in the name of surgery, of scalping, or removing a portion of the edge of the lid.

When the tarsus is much incurved, Burow's operation is a good one. The lid is everted, and a knife having been passed through the tarsus, it is divided with a stout pair of scissors into an upper and lower portion, the line of incision running about 3 mm. from the free edge of the lid along the groove which indicates where the lid is most curved.

The lower portion of the tarsus, bearing the cilia, is now only connected with the upper in a flail-like manner by the soft tissues. In order to prevent the return of the deformity it is a good addition to the operation to excise a fold of skin.

In Streatfeild's operation of grooving the tarsus, a fold of skin is removed as described on page 91, and a wedge-shaped horizontal gutter cut in the external surface of the tarsus by excision of a piece; in each operation the wound is brought together with sutures. To be really successful Streatfeild's operation requires great nicety in execution.

Transplantation of the ciliary edge is performed in many ways. Arlt's operation is the following: The eyelid is grasped in Snellen's compressing forceps (Fig. 20), which prevents all bleeding during the operation. It is then split into two layers for a distance of 3 mm. from its free edge. The anterior layer, which contains the lashes, is separated from its attachments, except at its two extremities, by making an horizontal incision through it 3 mm. from the edge of the lid. A

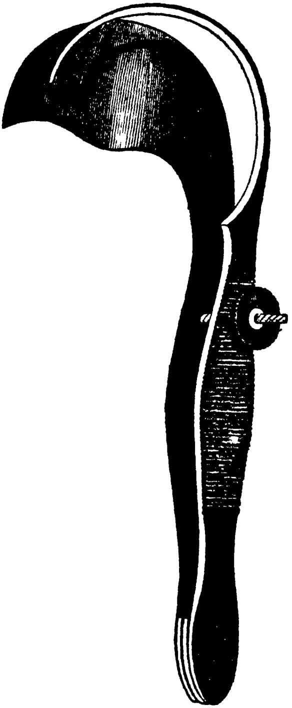

Fig. 20.—Snellen's Entropion Forceps.

fold of skin is excised from the lid above this, and the bridge of tissue containing the lashes is transplanted into the gap and fixed by sutures.

The objection to this operation is that the cicatricial contraction which takes place is not sufficiently opposed by the elastic skin, and the lashes sometimes again become drawn down. To obviate this tendency, the operation has been modified by Dianoux,* who, instead of removing the cutaneous flap, leaves it connected by its extremities (Fig. 21), and makes it and the cilia-bearing bridge change places by passing the former beneath the latter. The transplanted skin, when the lid is much incurved, is in contact with the cornea, and sometimes becomes converted into mucous membrane. Van Millingen, having split the lid, temporarily fixes the anterior flap containing the lashes to the brow with sutures, and lays rabbit's

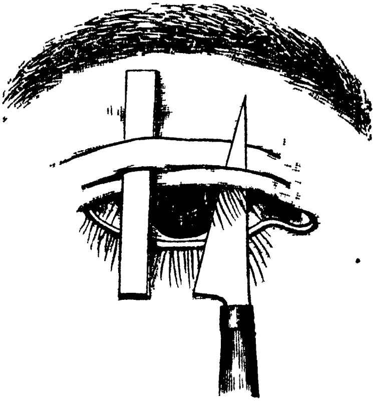

Fig. 21.—Dianoux's Operation for Entropion.

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* "Annales d'Oculistiques," 1882.

conjunctiva in the gap. Story* uses, for this purpose, a piece of mucous membrane from the patient's mouth. This can easily be dissected off the inner surface of the lower lip. The operation is much facilitated by compressing the lip with Snellen's forceps. As the mucous membrane curls up when removed, it is well previously to pass sutures into its four corners.

When only a portion of the lid is inverted, Spencer Watson's operation of making a ciliary and cutaneous flap with bases in opposite directions, and transposing them, is a good one (Fig. 22).

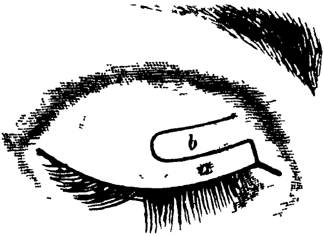

Fig. 22.—Spencer Watson's Operation.

Ectropion of either lid may be caused by the contraction of cicatrices, as from the healing of a burn, or fistula. That of the lower lid from very slight causes, such as chronic conjunctivitis, which has caused thickening of the mucous membrane, old tinea tarsi, where the lids are much thickened and the cilia shed, or paralysis of the orbicularis; in old people it sometimes occurs from mere laxity of the tissues of the lower lid. It varies in degree from a slight eversion of the lid margin, which just exposes the conjunctival surface, to a complete eversion, in which the ciliary edge is turned away from the globe, and is held down by the contracted integument. In the slighter cases the patient complains of the lacrymation, and the mucous edge is unsightly and liable to attacks of inflammation. In the severer cases the cornea suffers from the exposure, and the conjunctiva frequently becomes inflamed.

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* *Ophthalmic Review*, vol. iv. p. 72.

When due to paralysis of the orbicularis, this must be treated: when the eversion is only slight, but permanent, division of the canaliculus removes one of the most annoying symptoms, and with cleanliness, and the applications of astringents, considerable improvement can be produced. When the lower lid can be replaced, but readily becomes everted again, Argyll-Robertson's operation answers well. A piece of sheet lead about the size and shape of the lower tarsus is placed in the lower cul-de-sac; two needles, threaded to either extremity of a ligature, are then passed through the lid from without inwards, close to its edge, and about a centimetre apart; these are carried between the lead and the globe into the bottom of the cul-de-sac, and are brought out on to the skin; a piece of indiarubber tubing is then passed vertically beneath the loop outside the lid, and the ends of the ligature are drawn tight and tied over the tube below. In this way the lid is drawn into position and moulded against the lead. The ligature is removed after about ten days, when the position of the lid is usually maintained.

Another operation for ectropion of the lower lid is Adams', which consists in excising a V-shaped piece; it is, however, not a good principle to remove a portion of lid. Wharton Jones' operation is suitable for the same cases as Argyll-Robertson's. A V-shaped incision is made beneath the lower lid, its limbs reaching nearly to each canthus; the included triangular flap is dissected up till the lid is in good position, when the lower part of the wound is closed to form a vertical line, the V being thus converted into a Y. When the lid is adherent in its abnormal position, it is necessary to free it by dissection, and replace it, and then to fill up the gap left; this may be done by transplanting minute portions of skin as in treating ulcers elsewhere; by transplanting flaps which remain attached to their original position by means of a pedicle for a time, in which case the skin may be taken from the arm, which is bandaged into position for the purpose; or it may be taken from the region of the lid. Care must, however, be used so to plan the incisions that the contractions of the cicatrices do not reproduce the deformity. Lastly, if proper precautions be taken, considerable portions of skin can be transplanted without any pedicle, on the plan suggested by Wolfe. The skin must be of sufficient size to fill the gap without any traction, and should therefore be about a third larger in each diameter than the gap it is designed to fill; it must be freed from all subcutaneous fat, it should be kept from getting cold during the removal, and be secured by many sutures.

It is a good plan in most operations for ectropion to raw the margins of the lids, to unite them with sutures, and to keep them so for several weeks; the reproduction of the deformity by cicatricial contraction is thus prevented.

Tertiary syphilitic ulcer, rodent cancer, epithelioma occur in the eyelids, but as the principles on which they are to be diagnosed and treated are the same as in other parts of the body, they will not be considered here. Nævus of the eyelid sometimes extends into the orbital cavity, and is described in chapter xv. Primary syphilitic sores will be considered with affections of the conjunctiva, on which they more often occur.

Ankylo-blepharon is the name given to a union of the margins of the lids to each other; it is most commonly the result of burns, but may be caused by any ulceration of their margins; adhesion of any considerable extent of the eyelids is comparatively rare, but that of the part near the inner or outer canthus is common.

The treatment consists in separating the adherent lids with a scalpel, and in keeping the raw surfaces from coming into contact till healing is completed, by placing gold-beater's skin over them.

Symblepharon signifies an adhesion of the lid to the globe, and is nearly always the result of a burn of the opposed surfaces; it is unsightly, and limits the movements of the eye.

The treatment consists in dissecting the lid off from its abnormal attachment, and filling up the gap with conjunctiva. When the raw surface is only small, the mobility of the conjunctiva occasionally allows it to be brought together with sutures. When this is not feasible the gap may be filled by flaps of the adjacent conjunctiva, brought over it and fixed by sutures. Or portions of the conjunctiva of a rabbit, or mucous membrane from the patient's mouth, may be transplanted; considerable pieces may be thus used provided that they are placed *in situ* immediately upon their removal and secured by a sufficient number of sutures.

AFFECTIONS OF THE LACRYMAL APPARATUS.

These may concern the secreting parts, which consist of the lacrymal gland and its ducts or those concerned in removing the secretion from the eye, *i.e.* the canaliculi, lacrymal sac, and duct. (*See* Fig. 13.)

Inflammation of the lacrymal gland may be acute or chronic. The acute form is exceedingly rare, and presents symptoms which do not differ, except in the locality affected, from acute cellulitis, and the treatment required is the same.

Chronic inflammation is met with chiefly in scrofulous children, and is then usually associated with inflammation of the adjacent periosteum. A firm swelling, slightly tender, forms under the outer third of the supra-orbital ridge; it is often accompanied by œdema of the lid, or there may be a history of it occurring occasionally. Suppuration usually takes place, and is indicated by increased œdema and pain; the pus finds its way to the surface but slowly, and sometimes by several openings which contract into fistulæ that are difficult to cure.

Before suppuration has taken place, tonics and the local application of iodine should be tried. When it has occurred the pus should be evacuated, and every endeavour made to prevent the opening becoming fistulous. Should several fistulæ have already formed when the case comes under treatment, excision of the whole gland is usually the only plan that offers any hope of success.

Hypertrophy of the gland is occasionally met with, although many of the cases formerly so described were probably examples of adeno-sarcoma. The enlarged gland forms a painless, regular, but sometimes slightly lobulated projection beneath the supra-orbital ridge; usually it is immovable, but sometimes recedes slightly on pressure. There is no way of distinguishing with certainty enlargement of the gland from hypertrophy, and a very slowly growing sarcoma, and in some instances in which the swelling has been believed, even after removal, to be merely hypertrophic, it has recurred. When the enlargement exists on both sides, the chances of its nature being innocent are of course greater.

The writer recently had under his care a young woman with chronic symmetrical enlargements of each lacrymal gland. There was a doubtful history of syphilis four years previously. A course of iodide of potassium having proved ineffectual, the larger gland was excised. A section of the tumour resembled at first sight a round-celled sarcoma, but on more careful examination it was reported to be of a syphilitic nature. The swelling in the other orbit disappeared without further treatment.*

Malignant tumours of the lacrymal gland are indistinguishable from those growing from the periosteum in the same situation, and the distinction is not clinically important. In the more rapidly growing sarcomata and carcinomata the lymphatic glands over the parotid become involved early.

The diagnosis of the more slowly growing tumours is extremely difficult. Mr. Brudenell Carter has communicated to me the particulars of a case in which he removed from a girl of ten an orbital tumour which had the appearance of an indurated and hypertrophied lacrymal gland. Recurrence took place in about two years; it was again removed, and recurred after a similar interval. The third recurrence presented the symptoms of a sarcoma, and the eye was removed. A fourth recurrence took place and the orbit was emptied. Finally, the disease involved the cranial cavity and caused the patient's death nine years after the first operation.

When a tumour occurs in a person under middle life, is increasing not at all, or very slowly, and there are no other indications of malignancy, it may be treated by the local application of iodine, and the administration of iodide of potassium. When, however, the growth is decidedly increasing, a grave suspicion of its being of a malignant nature should be aroused, and no time be lost in removing it by operation. In patients who are past middle life the probabilities of the growth being malignant are so much greater, that it would be safer to operate at once.

Excision of the lacrymal gland is performed by making a horizontal incision through the upper lid, close to the orbit margin. The gland is then separated from the roof of the orbit with the handle of the scalpel, and seized with forceps; the other attachments are most easily divided with scissors. It should be remembered that there is often a small nodule of the gland separate from its main body; it is important to remove this also, for if it be left the secretion from it becomes extravasated into the cellular tissue, and gives rise to troublesome fistulæ.

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* Trans. Oph. Soc., vi.

Dacryoliths are concretions of the salts of the lacrymal secretion mixed with organic matter; they form hard masses in the gland or one of its ducts, and can be removed by incision.

Cysts occasionally occur from blocking and distension of one of the lacrymal ducts; they form smooth rounded swellings visible through the skin; they are best treated by excising a portion of the cyst wall from the conjunctival surface.

Fistulæ of the gland may follow suppuration as already mentioned, or may be due to the rupture of a cystic dilatation of a duct, or to an injury or operation. When the opening is small and only discharges tears, an attempt should be made to direct it to the conjunctival surface; this may be done by passing a seton through the cutaneous orifice to the conjunctiva; if this fails a double ligature may be used, the intervening portion of the lid being strangulated by tying them. When there are numerous fistulæ discharging pus, excision of the gland is the only treatment likely to be successful.

Affections of the drainage system are much more common; these may either prevent the tears from entering the canaliculi, or may obstruct their passage to the nose; under either of these conditions there will be overflow of tears, or "epiphora," but in the latter there will also be a swelling formed by the distension of the lacrymal sac by the retained secretion.

The secretion may fail to enter the canaliculus owing to its orifice being displaced or occluded. The causes which may lead to displacement of the lower punctum have already been considered.

Occlusion of the canaliculus may be the result of burns or other injuries, and is occasionally present at birth. Or it may be due to the impaction within it of an eyelash or other foreign body, or more rarely by a concretion formed from the tears, but containing in addition much organic matter. From whatever cause it arises an attempt should always be made to overcome it by the passage of a fine probe, and failing this, the little canal must be laid open with Weber's knife (Fig. 23).

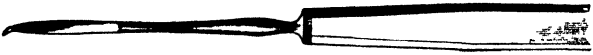

Fig. 23.—Weber's Canaliculus Knife.

This operation, which forms the preliminary proceeding in the treatment of many affections of the lacrymal passages, is performed as follows. The lower lid is slightly everted, and drawn outwards, so that the punctum is made accessible, and the angle in the canal, close to its commencement, is partially straightened; the probe-pointed end of the knife (Fig. 23) is then passed into the punctum, and as soon as it has entered, the handle is brought into an horizontal position; the point is then gently pushed on till it rests against the inner wall of the lacrymal sac; if it has reached this, firm resistance is experienced, and pressure upon the handle does not move the eyelid, as would be the case had the point caught in an obstruction in the canaliculus. The handle is now brought to a vertical position, the lid being kept quite tense, and the cutting edge being turned well towards the conjunctiva; as the knife is brought up to the vertical position the edge cuts its way out, thus converting the closed canal into a groove opening towards the conjunctiva. Sometimes, owing to the very small size of the lacrymal punctum, it is impossible to introduce the extremity of the knife; in such cases the orifice must be dilated by means of a fine conical probe (Bowman's director).

Obstruction in the lacrymal duct causes, in addition to the epiphora, symptoms which are due to the retention of the secretion in the lacrymal sac. A slight swelling is visible externally, and on pressing this the contents are either forced down the canal, or, as more commonly happens, they regurgitate into the conjunctival sac; at first they do not differ from pure lacrymal secretion, except in being slightly turbid; when, however, the fluid has been long retained, the mucous lining of the sac becomes irritated, probably owing to septic changes taking place, and there is an increased secretion of mucus. The chronic cystitis thus produced may at any time become acute, and go on to suppuration; the integument over the sac, and sometimes for a considerable distance around, then becomes red and tender. Sometimes pus regurgitates on pressure, often it is too thick to pass through the canaliculus, whose mucous lining is probably thickened; when this is the case, the wall of the sac soon ulcerates, and the pus either escapes by a direct opening, or burrows its way beneath the facial integument, on which it may open by several sinuses.

Stricture of the duct is common in women, but exceedingly rare in men, and it is not always easy to ascertain its cause. It may result from a catarrh spreading up from the nose, from periosteal inflammation, and possibly from an inflammation extending from the conjunctiva; in the majority of cases, however, the cause cannot be traced.

The treatment will depend upon the stage of the symptoms. When there is simple retention, which has only existed a short time, milder measures should be tried before dividing the canaliculus, as the obstruction may be due to temporary swelling of the mucous lining; the patient should be directed frequently to empty the sac by pressure, using at the same time some astringent and antiseptic lotion such as boracic acid. When the calibre of the canaliculus permits, it is an excellent plan to wash out the sac by injecting fluid with a fine syringe; this, however, frequently is only feasible when the canaliculus has been divided.

When there is inflammation of the sac no time should be lost in laying open the canaliculus, so as to allow free exit to the mucus or pus, and washing out the sac with an antiseptic solution. When there is acute inflammation it is often impossible, owing to the swelling of the tissues, to evert the lid sufficiently to insert the knife into the punctum lacrymale; in such a case an incision should be made through the integument into the sac; the direction of this should be downwards and outwards, in order that when the inflammatory swelling subsides the cicatrix may correspond with the natural furrow and be unnoticeable. Although a spontaneous opening frequently becomes fistulous, this rarely occurs with an incision. The inflammation usually rapidly subsides, and the canaliculus may then be divided, and the stricture be dilated by the passage of probes.

Lacrymal probes are made in various patterns. A very convenient form is that shown in Fig. 24; these go by the name of Couper's probes. Some surgeons, however, prefer an instrument with a more globular bulb at the end. In passing a probe the lid is drawn down and put slightly on the stretch, the probe is then passed horizontally until it impinges against the inner wall of the sac; if the canaliculus has been

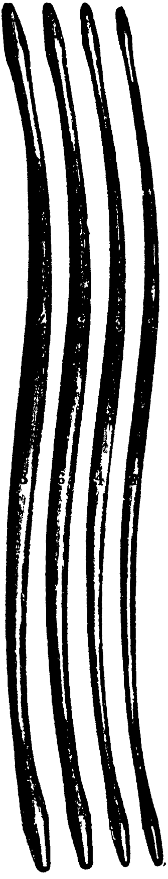

Fig. 24 — Couper's Lacrymal Probes.

freely divided it meets with no resistance so far. It is then brought to the vertical position, the concavity of the lower curve being directed forwards, and passed gently downwards, with a slight inclination outwards. When the resistance of the stricture is felt the pressure may be slightly increased; as soon as the head of the probe has passed the stricture all sense of resistance ceases owing to the narrower part of the probe coming into the constriction; this is one of the advantages of this form of probe over the conical probe of Weber. The treatment should be commenced by the passage of a probe that passes without much force being required, and without causing any bleeding. At intervals of two or three days a probe should be passed, the size being increased as soon as the one previously used passes easily. It is important to avoid any laceration of the mucous membrane, as this may be followed by cicatricial contraction. The operation is often painful; cocaine dropped into the canaliculus, or injected into the sac, will sometimes produce sufficient anæsthesia, but is rather uncertain in its action; when general anæsthesia is required, nitrous oxide gas answers the purpose admirably. In old strictures the mucous membrane is sometimes very callous, and little pain is experienced. When a probe whose diameter at the widest part is 3 mm., can be passed easily, no further dilatation is necessary, but the instrument should be passed again after a few weeks in order to ascertain that no recontraction has taken place. To prevent this, some surgeons pass a bent wire or "style" into the canal, and leave it in; the upper part forms a right angle with the remainder, and lies out of sight in the canaliculus. This method of treatment was more widely adopted formerly, when probes of smaller size were employed, and is now seldom necessary. When there is a tendency to recontraction, the plan suggested by Mr. Benson may be adopted, of teaching the patient to pass a style for himself, and letting him wear it at night-time for several months. As the curvature required varies in different cases, it is well to use a flexible leaden instrument until the best shape has been ascertained. When a stricture recontracts very rapidly, and is very rigid, Stilling's plan may be adopted of passing a stout knife through the constriction, and dividing it freely by several radiating cuts; a large probe should afterwards be passed and left in about half an hour.

Electrolysis has recently been used successfully for the dilatation of the canaliculi,* and with a few modifications may be found to be applicable to strictures of the duct. A metallic probe is passed through the constriction and connected with the *negative* pole, a weak current is then passed for a few minutes, and it is then found that the probe which before fitted tightly lies loose in the canal. The probe must on no account be connected with the positive pole.

When fistulæ have already formed the treatment is often very unsatisfactory. Attempts should be made to render the sac and the track of the sinus aseptic, at the same time the stricture should be dilated. The fistula will then sometimes close spontaneously, or may be induced to do so if its edges are refreshed with the knife or galvanic cautery. In old-standing cases, however, the stricture is sometimes incurable, and it is impossible to keep the dilated sac and tortuous fistula free from suppuration while the tears are constantly passing through them. In such cases, when the measures indicated have been vainly tried, it is justifiable to obliterate the lacrymal sac. This can be done by laying it open and removing its mucous lining either with the knife or caustic, so that the opposite walls may adhere. The patient will of course still suffer from overflow of tears, but this is an evil to which he will have been long accustomed. If it causes him inconvenience it can be arrested by excising the lacrymal gland.

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* Dr. Stevenson and Mr. Jessop; *Brit. Med. Journal*, ii.; 1887.

AFFECTIONS OF THE CONJUNCTIVA.

In considering affections of the conjunctiva, the continuity of the palpebral, scleral, and corneal portions must be borne in mind, as well as the differences in their structure. Some morbid conditions affect one portion more than the others, but most have a tendency, if unchecked, to invade all to some extent. Inflammatory affections, however, present very different symptoms in the three portions. In the palpebral portion increased secretion, and loss of smoothness; in the scleral, increased vascularity, and œdema or chemosis; and in the corneal, development of blood-vessels and loss of transparency are the prominent features. Affections which attack the corneal epithelium primarily will be considered in chapter iv.

Conjunctivitis may be conveniently divided into three chief varieties: simple hyperæmia, which is not generally classed among inflammatory conditions, but is not separated from them by any sharp boundary line; catarrhal conjunctivitis, in which there is increased vascularity combined with increased secretion of mucus mixed with inflammatory products; and purulent conjunctivitis, in which, together with these symptoms, there is a formation of pus. The boundary lines between these, and especially between the two latter, are not always sharply defined; the less severe forms may develop into the more severe, the purulent form as it recovers passes through stages which are indistinguishable from catarrh and hyperæmia, while the secretion from a case of either purulent or catarrhal ophthalmia may produce either form when inoculated into another eye. It seems probable, therefore, at any rate in many instances, that these two affections differ from each other in degree rather than in kind.

Besides these, there are a few other inflammatory affections which are frequently associated with them.

Hyperæmia of the conjunctiva may result from many causes, as the irritation produced by cold wind, dust, or irritating vapours, such as tobacco-smoke; overwork of the eyes, either actual, or relatively to their capabilities. In the latter category must be included the cases in which an error of refraction, or defective power either of the ciliary or the recti muscles, calls for excessive effort. The conjunctiva participates in the dilatation of the facial vessels caused by exposure to the weather, or indulgence in alcoholic excess. A chronic hyperæmia is often seen in persons who are past middle life, and live freely; in such there are generally dyspeptic symptoms, and often a gouty tendency.

A special form of hyperæmia accompanied by intense photophobia and severe burning or smarting pain, occasionally results from exposure to glare, as from snow or the electric light.

Hyperæmia shows itself, as might be expected, chiefly in the scleral portion, although the palpebral is also affected.

The amount of injection varies; in the worst cases, the whole of the ocular conjunctiva presents a network, with very irregular meshes, formed by dilated and tortuous vessels; these can be moved over the surface of the eye by rubbing the lid over them, and they can be emptied by slight pressure; in both respects, as well as in not being especially marked in the circumcorneal zone, differing from the dilated vessels seen in inflammation of the cornea or iris. Sometimes one of the dilated vessels will give way, and blood be extravasated beneath the conjunctiva. In slighter cases there are fewer dilated vessels, and in some they only become visible after prolonged use of the eyes, or after exposure to wind, etc.

The treatment consists in discovering the cause and removing it; during the continuance of the hyperæmia the eyes should be protected from glare and dust by wearing faintly tinted glasses, and work by artificial light should be avoided. A mild astringent (Formula 2 or 12, Appendix D) should be applied to the conjunctiva three or four times a day. The most troublesome are the gouty and dyspeptic cases. When the injection has existed long, the vessels appear to become permanently dilated. The condition is unsightly, but does not always cause discomfort.

Catarrhal conjunctivitis (catarrhal, or mucopurulent, ophthalmia) occurs in all grades of severity; the slighter cases can with difficulty be distinguished from simple hyperæmia, the more severe are separated by no defined boundary from purulent ophthalmia. There can be no doubt that most cases are contagious, and it is possible that all are. In the more severe cases the gonococcus is to be found in the secretion, and it is possible that its contagious properties may be due only to its presence. The susceptibility to infection varies much, underfed and scrofulous children are especially prone to be attacked, and the liability is increased when the follicular granulations, to be presently described, are visible in the lower cul-de-sac. Some cases are probably the further development of neglected hyperæmia; in children measles and scarlet fever are common causes.

The symptoms vary with the acuteness of the attack and the age of the patient; speaking broadly, one may say that photophobia and spasm of the orbicularis are the conspicuous features in the child, and increased secretion in older patients. The symptoms consist in redness of the edges of the lids, increased vascularity of the palpebral, and usually also of the ocular, conjunctiva, and glueing of the eyelids together by mucus, which sometimes coagulates and forms stringy masses. When the affection has existed for some time, it is not uncommon for superficial ulcers to form on the cornea, when the photophobia is generally greatly increased. In very young children this latter symptom is always present, and usually causes the patient to bury his head in the bed or in the nurse's lap. There is often at the same time so tight a contraction of the orbicularis, and so much rolling up of the eye when the lids are separated, that it is difficult to ascertain the condition of the cornea. This "blepharo-spasm" is not only an obstacle to diagnosis and treatment, but is directly injurious by the pressure upon the eye, and the retention of the secretion which it causes. When it has existed long there is usually a mucous chink, or line of ulceration, to be seen running a short distance outwards from the outer canthus, indicating the position where the skin has been folded together. When this exists, and the symptoms are still severe, much good is often done by making an incision through the chink with scissors, thus dividing a few fibres of the orbicularis muscle. In order to examine the eyes the infant should be laid on its back on the knee of the attendant, its head resting on, and slightly between, the surgeon's knees; the latter then lays his thumbs gently on the eyelids close to their margins, and waits for an unguarded moment, when he will often succeed in separating them sufficiently to ascertain the condition of the cornea; if this manœuvre fails, or if the eye is rotated upwards too much, the choice will lie between raising the upper lid with a Desmarres's retractor or administering an anæsthetic; in babies the former is the best, in older children a struggle is to be avoided, as it increases the spasm and congestion, and the recollection of it renders the child intractable at a later visit. A view of the cornea can sometimes be obtained by turning the child away from the window, and then throwing the light on the eye from the ophthalmoscope mirror. If this fail, general anæsthesia must be induced. Sometimes in young children, notwithstanding extreme photophobia, nothing abnormal is to be seen beyond slight hyperæmia. Occasionally acute catarrhal ophthalmia with intense photophobia, and œdema of the lids, without much increased secretion occurs in adults; usually, however, in these the inflammatory symptoms are slight, and the mucous secretion more abundant.

When catarrhal ophthalmia has existed a long time, the papillæ of the palpebral conjunctiva become hypertrophied, so that the surface has a velvety appearance. The vessels of ocular conjunctiva also encroach on the most peripheral zone of the cornea, in which they usually appear as fine vascular loops. More rarely, and chiefly in scrofulous subjects, these loops of vessels are so closely aggregated, that they form a uniform red surface; this condition is generally most marked above and below, where there is formed a crescentic area extending a few millimetres on to the cornea immediately beneath the epithelium, which it slightly raises; the free edge of each crescent is bounded by a fine grey line formed by opaque epithelium. This condition is somewhat analogous to that of pannus produced by granular lids, but differs from it chiefly in the fact that the vessels appear to lie somewhat deeper, coming from the vascular loops of anastomosis between the superficial and deep vessels, and not as in pannus, directly from the conjunctival vessels; the surface of the epithelium, moreover, remains smooth, while in pannus it is always rough.

In all affections of the conjunctiva, accompanied by excessive secretion, bandages should be avoided, as they prevent the discharge from escaping. In acute cases in adults iced compresses* are very comforting, and in the earlier stage of great benefit. The measures chiefly to be relied upon are great cleanliness, the discharge being frequently washed away, and the use of mild astringent lotions (Formulæ 2, 12, or 16, Appendix D), introduced into the conjunctiva sac every few hours. It is a good rule to remember in all conjunctival affections that the more secretion there is from the surface, the stronger may be the astringents, but they are dangerous when there is much infiltration of the conjunctiva without secretion. An acute attack of conjunctivitis, if recent, can sometimes be rendered abortive by cocainising the eye, everting the eyelids, brushing the conjunctiva over with a solution of nitrate of silver (gr. xxx. to the oz.), and applying iced compresses. As in all cases in which solutions of nitrate of silver of a greater strength than 15 grs. to the ounce are used, the lids should afterwards be well washed with water; some surgeons always use before this a weak solution of common salt in order to neutralise any caustic that may remain, a precaution that is very necessary when using nitrate of silver in its solid form. When the edges of the lids are excoriated a little vaseline may be applied to them. The photophobia can be relieved by atropine, or cocaine; the former may be combined with an astringent lotion; the cocaine should be given separately in the form of drops of the strength of about five per cent., which may be used three or four times a day, three or four instillations being made with an interval of about a minute between each. When in children the photophobia is in excess of the other symptoms, it can be sometimes cured by dipping the head suddenly into cold water. There are, however, obvious objections to the plan, and it is well to reserve it for cases in which, owing to the intractability of the patient, cocaine cannot be efficiently used.

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* **For the method of applying these *see* page 368.**

In chronic cases the child should go out every day, avoiding bright sunlight and having the eyes well covered by a large shade.

The patient or friends should be cautioned as to the contagious nature of the affection.

Purulent ophthalmia is a much more serious affection, since the whole thickness of the conjunctiva and the subjunctival tissues are infiltrated with the inflammatory exudation, and the nutrition of the whole cornea may consequently be impaired.

There is little doubt but that it is always due to contagion, although the source of it cannot always be traced. The gonococcus can always be found in the secretion, and the affection is probably in all cases identical with gonorrhœal inflammation. But the name "gonorrhœal ophthalmia" is usually only given to purulent conjunctivitis, when it is set by direct inoculation with pus from the urethra. Owing either to a larger number of microbes being introduced, or to their greater activity, the inflammation is then particularly violent. The comparative mildness of other cases of purulent ophthalmia may perhaps be due to the character of the microbe having been modified by transmission through several individuals.

It will be convenient to consider separately purulent ophthalmia as it affects the new-born child and older subjects.

Ophthalmia neonatorum is due to inoculation of the eyes with vaginal secretions; usually this occurs either during the passage of the head, or immediately after birth when the eyes are opened, or from carelessness of the nurse in washing the infant, but it has been known to take place *in utero*. The symptoms appear between the second and the fifth day. When they appear later they are probably due to subsequent inoculation. They first show themselves by puffiness of the lids, and glueing of their margins together, the whole conjunctiva is injected, and soon becomes covered with a purulent secretion, which is formed chiefly by the palpebral portion. The papillæ become much hypertrophied, the ocular conjunctiva much chemosed, often forming a prominent wall round the cornea, which seems to lie at the bottom of a depression. Sometimes the œdema of the lids and conjunctiva is so great that the cornea is only seen with the greatest difficulty. The secretion of pus is usually very copious. If untreated, in a large number of cases the cornea either sloughs as a whole, or becomes extensively ulcerated. The former is the result of its nutrition being impaired by compression of the blood-vessels, and its onset is indicated by the whole surface losing its lustre, and presenting an appearance resembling a dead eye. Partial ulceration is also favoured by the impeded circulation; and it is probable that when once the epithelium has desquamated the inoculation of the corneal lymph spaces with the pus has a deleterious effect. Such ulcers very commonly perforate; the final result will depend upon their size and situation. A large ulcer may heal, but the cicatrix, being unable to resist the intraocular pressure, becomes distended into a hemispherical protuberance, or "staphyloma." When the perforation is peripheral the iris prolapses into, and becomes adherent to, the opening; when central, the lens is pushed forwards and blocks the opening, lymph is thrown out upon the exposed surface of the capsule, and as the aqueous is re-secreted the lens is forced back into its normal position, carrying with it the little nodule of lymph, which forms a permanent opacity on the anterior capsule (pyramidal cataract).

The treatment of ophthalmia neonatorum consists in removing the discharge, checking its formation, and in guarding against and treating corneal complications. The first indication must be fulfilled by separating the lids, and irrigating the eye with water or some antiseptic solution, as boric acid or perchloride of mercury (Formula 19); in severe cases this must be done every quarter of an hour by the nurse, and once a day by the surgeon, who should if possible evert the lids. To facilitate the irrigation a special instrument has been designed by Mr. Edgar Brown. This resembles an ordinary spring eye-speculum, but the limbs are hollow, and that part of them that lies beneath the lids is perforated by numerous fine openings; the instrument being connected with an indiarubber tube, fluid can be readily injected into either cul-de-sac. If this instrument is not at hand, the substitute suggested by Dr. Story will answer the purpose equally well. This consists of a piece of small drainage tubing, stiffened with wire, bent into the required shape, and perforated where necessary. When the irrigation has to be entrusted to unskilled hands, one person should hold the lids apart, while another allows a stream from a large sponge to fall in the eye from a height of about four inches.

The secretion can be checked by dropping into the eye every half-hour a solution of nitrate of silver (Formula 4, Appendix D). In addition to this, every day, or every other day, the surgeon should evert the lids, and after thorough cleansing, brush the exposed conjunctiva over with a solution of ten or fifteen grains. Other applications have been recommended, and may be used; one of the best being iodoform, which may be used in the form of an ointment (Formula 33, Appendix D). Nitrate of silver, however, answers every purpose so well that there is little inducement to substitute anything for it. If the treatment is properly carried out the secretion should diminish perceptibly by the second or third day; the formation of a discharge, however, which gradually assumes the character of mucus, generally continues for several weeks, and the papillæ of the conjunctiva often remain hypertrophied still longer. When the discharge is no longer distinctly purulent, milder astringents (Formulæ 15, 16, Appendix D) may be substituted for the nitrate of silver; indeed, it is well not to employ the latter for a very extended period, or it may produce a permanent brown stain of the conjunctiva and sclerotic which cannot be removed. When the disease has assumed the characters of catarrhal ophthalmia it may be treated as such. If the nutrition of the cornea seems imperilled by the chemosis, the swollen conjunctiva should be snipped with scissors in several situations. In ulceration of the cornea, either eserine or quinine should be used as drops (*see* chapter iv.), and the other treatment continued.

Although an immense number of eyes are lost annually from this disease, it is one that is exceedingly amenable to treatment, and no case ought to be lost in which the corneæ are clear when the treatment is commenced. It is absolutely necessary that the lids should be well opened, and if owing to the great swelling this is impossible, either the outer canthus must be divided, or, as suggested by the late Mr. Critchett, the upper lid be slit vertically. This latter proceeding, although giving more room than the former, is objectionable on account of the risk of a conspicuous cicatrix remaining. In all lying-in institutions a routine practice should be made of washing the child's eyes immediately after birth with an antiseptic solution.

Purulent ophthalmia in adults (gonorrhœal ophthalmia) is a much more severe affection, owing to the unyielding nature of the tissues, and the consequent greater danger to the cornea. The latter not unfrequently becomes ulcerated near the margin where it is overlapped by the conjunctiva; such an ulcer sometimes eats its way round a considerable part of the corneal circumference, and, by cutting off its nutrition, may cause the whole membrane to slough; or it may perforate at one spot, and cause a large prolapse of the iris, or be followed by intra-ocular suppuration. The treatment does not differ in principle from that recommended for ophthalmia neonatorum, but since one eye is usually first affected, the surgeon's first care should be to protect the other. This can be best done by means of "Buller's shield," which consists of a watch glass, mounted in a frame of strapping, which is fixed to the skin round the orbit. This answers the threefold purpose of allowing the patient to see with the eye, of permitting the surgeon to examine it, and affording efficient protection against inoculation. In the early stage, and in the absence of corneal complications, iced compresses are serviceable; when, as occasionally happens, there is much infiltration of the conjunctiva, and but little secretion, astringents must be used cautiously, and reliance be placed upon scarification and iced compresses. When the swelling of the lids is so great as to render their eversion impossible, and the opening of the eye beyond a limited extent very difficult, instead of liquid applications the ointment of iodoform may be used, as already described. In nearly all cases of purulent ophthalmia, the hypertrophied papillæ continue for a long time to secrete a thin watery pus.

Corneal complications must be treated upon the principles laid down in the chapter devoted to diseases of that membrane.

Granular ophthalmia (granular lids, trachoma) is intimately associated with catarrhal ophthalmia; in an epidemic of the latter there are always many cases of this affection, and there is some evidence to show that either affection may cause the other by direct contagion. In the substance of the granulations a diplococcus has been found, very similar to the gonococcus, but smaller, and inoculation with cultures from it have set up trachomatous conjunctivitis.*

The inflammatory symptoms in the early stage do not differ from those of slight catarrhal ophthalmia; the photophobia is not, however, as a rule, very great. The lids, especially the lower, are swollen a little beyond their edges, so that they look unusually convex. If they be everted, the "granulations" which give the name to this affection are immediately seen. These are of two kinds, which may coexist. In the *follicular* variety the lid, except near its free edge, presents numerous greyish-red, semitransparent bodies of round or oval form, having much the appearance of boiled sago-grains; they are most numerous in the lower cul-de-sac, and may exist there only. They consist of collections of lymphoid corpuscles, enclosed in the meshes of a delicate reticulum, the whole being invested by a capsule, formed by a condensation of the normal tissue.* It is still a disputed point whether these lymph follicles are entirely pathological formations, or whether they are due to hypertrophy of normal structures. The surface of the conjunctiva is generally abnormally vascular and rough from hypertrophy of its papillæ. Frequently, in this condition, there is an almost complete absence of inflammatory symptoms, or merely an itching, irritable sensation, and slight cohesion of the lids on rising in the morning.

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* Michel: "Archives of Ophthal.," 1886.

In the *papillary* form, the surface is studded over with villous processes, which vary somewhat in appearance; some have rather obtuse summits, separated by deep chinks, and are somewhat hard, and both in these respects and in the whitish colour which they usually possess, they differ from the hypertrophied papillæ often left after purulent ophthalmia, these latter being soft and fleshy, and very vascular. Near their surface the papillæ consist chiefly of exudation cells, but in the deeper portions is organised fibrous tissue, which may extend a considerable distance into the substance of the lid.

Granular ophthalmia is intimately associated with catarrh, and is frequently complicated by attacks of the latter affection. As the fibrous material at the base of the granulations increases in quantity, and commences to undergo contraction, the supply of blood to the surface becomes lessened, the granulations become paler and harder, and cease to grow; finally, as the fibrous tissue creeps higher, they atrophy and disappear, and the surface of the lid may become almost smooth again, but it never resumes its normal appearance. The normal arrangement of fine parallel vessels, immediately beneath a surface which is kept moist by its own secretion, gives place to a whitish appearance, in which either no vessels are visible, or a few large isolated ones; the white material is often condensed into bands, which appear to interlace in different directions, leaving shallow depressions between them which give the lid a somewhat honeycombed appearance. As the contraction increases the lid becomes curved inwards (entropion), and if the cicatricial matter extend well up towards the cul-de-sac, the movements of the lids are impeded, and the palpebral fissure narrowed.

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* **Pollock: "Histology of the Eye."**

During the existence of the granulations, it is not unusual for the corneal epithelium to become thickened and rough, while vessels extend on to it and beneath it from the conjunctiva. This condition of "pannus" will be described more fully in chapter iv. The exact connection between the pannus and the granulations is not known; but since it is always at first confined to the part covered by the lid, it is generally assumed that the friction of the lids has some share in its production; it is not improbable, however, that direct extension of the disease along the conjunctiva has something to do with it.

Not only are lids that are granular peculiarly susceptible to the contagion of catarrhal ophthalmia, but they are almost equally so to the purulent form. When an attack of purulent ophthalmia subsides, it is not at all an unfrequent occurrence for the granulations and the pannus to disappear, a fact that has been utilised in treating severe cases.

The prevalence of trachoma in different countries bears a direct relation to the dirty habits of the people, and to the facilities offered for contagion. It is common in most Eastern countries, and its especial prevalence in Egypt has given one of the names to the disease. In Western Europe it was formerly endemic in most standing armies, and was not unfrequently designated "military ophthalmia."

In more modern times, an extensive field for trachoma has been opened by the establishment of large schools for pauper children, and other pseudo-charitable institutions, in which the arrangement of the dormitories and lavatories were such as to facilitate contagion, and the general condition of the inmates and the dietary such as to render them peculiarly susceptible. In such circumstances trachoma and catarrhal ophthalmia were often endemic, fresh inmates becoming affected and in turn transmitting the disease, so that the institution was never free. Frequently, however, the disease would break out in a more virulent form, and invade almost the entire institution. In all such epidemics it is to be noticed that all are not affected in the same manner, the follicular and papillary granulation and catarrhal ophthalmia all occurring, and apparently originated from the same source of infection. Those whose lids are already granular are more susceptible to the contagion of catarrhal ophthalmia, while the existence of catarrh facilitates the propagation of the infecting material to others.

Although, however, contagion is the most fruitful source of trachoma, the follicular granulations do occasionally occur in anæmic and underfed children, and may long remain unaccompanied by inflammatory symptoms; in such there is often no history of contagion to be obtained, although it is, of course, impossible to exclude it with certainty.

In the treatment of granular ophthalmia, it is absolutely necessary that the astringents employed should be applied to the whole surface affected by the granulations, and this can only be done by fully everting the lid. Many applications have been employed (Formulæ 14, 17). One or other of these should be applied to the everted lids at least twice a week, by the surgeon, while the patient may himself use a weaker astringent lotion (Formulæ 2, 3, 7, 15, 16) several times a day. When the patient is sufficiently intelligent, he should be instructed to evert the eyelids once or twice daily, and to apply the lapis divinus (Formula 14, Appendix D), or the smooth surface of a crystal of sulphate of copper. Strong caustics must be avoided, for although they destroy the granulations, they increase the amount of cicatricial tissue, and so favour contraction. The effect of the caustic should never extend below the epithelium, and a fresh application should not be made till the epithelium destroyed by the previous one has been replaced.

Since an attack of purulent ophthalmia often is followed by the disappearance of the granulations, inoculation with matter from a case of ophthalmia neonatorum has occasionally been resorted to. This is only justifiable when the whole of the cornea is affected by pannus, since it is then less liable to slough than in its natural non-vascular condition, although even then the proceeding is not wholly free from risk.

A much safer mode of obtaining the same end is to bathe the eyes three times a day for two or three days with an infusion of the seeds of jequirity formed by macerating about a drachm and a half of the seeds in a pint of water for twenty-four hours. A severe attack of muco-purulent ophthalmia results accompanied by great swelling of the eyelids and an abundance of stringy secretion. There is often also a good deal of constitutional disturbance. The inflammation is allowed to run its course unchecked, and subsides in about ten days or a fortnight. During the whole period the patient must be kept confined to one room. When the inflammation subsides, the cornea will often be found to have cleared considerably. Although infinitely safer than inoculation, the treatment by jequirity is not free from risk of sloughing of the cornea. It is well, therefore, to use it in one eye first, the other being carefully protected by a Buller's shield. The cases in which it answers best are those of old-standing pannus, in which the granulations are hard and pale, and the secretion absent or scanty.

When called upon to treat an epidemic of catarrhal ophthalmia, the surgeon's first care should be to separate the healthy from those already infected. All conditions likely to favour the spread of the disease should be removed; one of the most frequent of these is the custom of allowing several children to use the same towel, and another overcrowding and defective ventilation of the dormitories. The diet-table and general hygienic condition of the institution must be thoroughly examined, and defects remedied. The whole non-infected portion of the school should be inspected every morning by some competent person in order to detect the first appearance of the symptoms. To eradicate the disease rigorous supervision is required for at least a year, and then some chronic cases may remain, and be a source of future danger.

Diphtheritic conjunctivitis is exceedingly rare in this country. It occurs during epidemics of diphtheria, but is not necessarily accompanied by that disease in the individual. There are marked inflammatory symptoms, and the eyelids and conjunctiva are much swollen, but there is little or no liquid secretion; a layer of exudation or false membrane can be seen lying on the conjunctiva, and when this is peeled off, a raw and bleeding surface is left. The treatment consists in avoiding astringents, applying cold, scarifying the conjunctiva, and administering quinine internally. This affection has nothing in common with cases of catarrhal and purulent ophthalmia, in which the secretion coagulates.

Phlyctenular ophthalmia (scrofulous ophthalmia) is an inflammation of the conjunctiva, chiefly its scleral portion, characterised by the appearance of one or more white vesicles close to the corneal margin, containing a collection of leucocytes. To each there usually runs a leash of dilated vessels, and the adjacent conjunctiva is frequently injected. The phlyctenulæ may lie on the cornea itself. Usually each is about a millimetre in diameter, but sometimes they measure two or three millimetres; when the vesicles are large the name of "pustular ophthalmia" is often given to the affection. The smaller phlyctenulæ usually break down, discharge their contents and disappear, after having existed about ten days. The larger pustules, when situated near the cornea margin, not unfrequently develop into perforating ulcers. Phlyctenular ophthalmia affects strumous children more than others, and has a great tendency to recur. It is often associated with catarrhal ophthalmia.

Although believed to be of constitutional origin, the slighter cases of phlyctenular ophthalmia usually recover quickly under local treatment—such as Pagenstecher's ointment (Formula 30). The insufflation of calomel, or boric acid reduced to a soft powder, answers well, but it is difficult for the patient's friends to carry out. When there is much photophobia, cocaine may be used either alone, or combined with the ointment. The eyes should be shaded from the light when out of doors. Errors of diet, especially indulgence in pastry and sweetmeats, act as predisposing causes, and by some it is thought that the irritation from carious teeth may induce the affection. In the case of recurrent attacks ferruginous tonics, open-air exercise, and perhaps change of air, may be required. These cases are analogous to recurrent vascular ulcers of the cornea, and call for the same treatment.

Pterygium, so called from its fancied resemblance to the wing of an insect, is the name given to a thickening of the conjunctiva, limited to a triangular area, which has its apex directed towards the centre of the cornea, and its base towards the inner or outer canthus, or, very rarely, upwards or downwards. The apex is somewhat truncated, is firmly attached to the surface of the cornea, but does not extend deeply into its substance, and is of a greyish colour. The body of the pterygium varies in colour, but is usually much more vascular than the rest of the conjunctiva; the vessels always run a straight course, parallel to each other. A probe can usually be passed a considerable distance beneath its upper and lower border, and sometimes, near the cornea, completely beneath the whole growth. The affection is seldom seen till after middle life.

Exposure of the eyes to wind and dust, and all other conditions which cause chronic hyperæmia of the conjunctiva, act as predisposing causes, but an abrasion of the corneal epithelium, as from a superficial ulcer, is probably necessary; the vessels from the conjunctiva running to this cause hypertrophy in their track, and as they extend farther on to the cornea they drag the conjunctiva in the same direction, and thus produce a folding over, which gives the apparent freedom to the borders of the pterygium. If the eye is still exposed to the same conditions which caused the pterygium, the latter often continues to increase, covering more and more of the cornea, and thus interfering mechanically with vision.

Recently the view has been advanced that the pterygium is due to the presence of a micro-organism, but the evidence on this point is not conclusive.

If the growth extends in front of the pupil, or if it is increasing, it should be removed. This may be done by simply dissecting it off from apex to base; not unfrequently it reappears during the cicatrisation of the conjunctival wound. A more efficacious method is to strangulate it with three ligatures, one near its apex, another at its base, and a third which constricts the attachment of its deep surface. These are applied by passing a needle armed with a double thread first beneath the apex, and then beneath the base; the threads are then cut close to the needle, thus giving the three ligatures required. A better proceeding than either of these is to transplant the apex to a situation where it will be out of sight. The apex is dissected up, and an incision is then made in the conjunctiva sufficiently far below the cornea to be covered by the lower lid; into this the apex is fixed with sutures, while the gap left by the removal of the growth is filled up by bringing the conjunctiva together. Or the apex may be simply turned back upon the body of the growth, and fixed on its deeper surface, as suggested by Mr. Nettleship.

Lupus occasionally affects the palpebral conjunctiva; it forms an irregular swelling, entirely free from induration, and not unlike that which follows a chalazion that has suppurated; the co-existence of lupus on the face would arouse a suspicion of its nature.

A hard chancre is sometimes seen in this situation; the appearance is that of an irregular ragged ulcer, with a very indurated base; the lymphatic gland over the parotid is always affected. A difficulty might occur in distinguishing between it and epithelioma, but the latter is of slower growth, and the edges are more raised.

Xerosis of the conjunctiva is a rare condition in which the membrane becomes thickened and dry, and undergoes a gradual contraction which narrows the palpebral fissure, causes obliteration of the culs-de-sac, and impairs the movements of the eyes and lids. From this, and the absence of moisture, the corneal epithelium becomes hard and horn-like, and the membrane opaque.

It is considered by some to be a form of pemphigus of the conjunctiva, partly because it is sometimes preceded by a vesicle, and partly because it has been seen in association with that eruption.

Treatment does not appear to be of much avail. Attempts have been made to keep the conjunctiva moist with glycerine, but without much success, and the affected conjunctiva has been dissected off and replaced by that taken from a living rabbit; I believe, however, that no case of recovery has been recorded.*

W A F

CHAPTER IV.

THE CORNEA, AND THE ANTERIOR ZONE OF THE SCLERA.

THE diseases of the cornea are such as to call for the most careful attention of practitioners. The membrane may be described as forming the window of the eye, and any flaw in it is fatal to the perfection of vision. It is liable to be affected by disease in two principal ways: either by alteration in its curvature, or by diminution of its transparency; and the chief object of treatment is to prevent either of these changes from being produced.

·Apart from wounds and injuries, which will be discussed in the chapter specially devoted to them, the cornea is liable to suffer from a defect of shape incidental to atrophy of its central portion, from several forms of inflammation and of ulceration, and from abscess.

Conical cornea.—The defect of shape incidental to atrophy of the central portion is that commonly known as conical cornea, or keratoconus. In this, the centre of the cornea, or the part most remote from the sources of vascular supply, becomes thinned and weakened, and gradually yields to the pressure from within of the fluid contents of the eyeball, and to the traction exerted by the external ocular muscles. The result is a central projection, more or less irregularly conoidal in outline, the true shape of which is readily seen in profile (Fig. 25), but which, when fully developed and viewed from the front, produces an effect as if the centre of the cornea were occupied by a pellucid and highly refracting drop of fluid. The projection of the cone gradually increases, and, as it does so, vision suffers in a continually increasing degree. The first effect of the change is to elongate the axis of the eyeball, and thus to produce a sort of myopia; but, as the yielding is generally greater in one meridian than in others, the myopia may from the first be attended by astigmatism. The distortion of the cornea, moreover, is greater at the centre than nearer to the circumference, and hence the degree, whether of myopia or of astigmatism, is not uniform over the whole surface, and, consequently, cannot be corrected for the whole surface by any single glass. When a form of myopia, or of myopic astigmatism, is met with, in which the best possible combination of spherical and cylindrical glasses leaves the vision decidedly below the normal standard, conical cornea should be suspected and looked for, more especially in young women, in whom the larger number of such cases is met with. A well-developed stage of the affection is readily recognised, either by the manifest shape of the cornea when seen in profile, or by the peculiar appearance of a bright drop in the

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* For further information on this subject the reader is referred to the Trans. Ophthal. Soc., 1886; pp. 124-133.

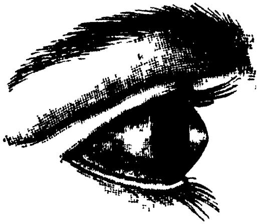

Fig. 25.—Conical Cornea.

centre of the eye when it is seen from the front; but the detection of the earlier stages is best accomplished by the aid of the shadow test, the value of which, for this purpose, was pointed out by Sir William Bowman long before it was employed in the general investigation of errors of refraction. If this test be employed, as directed in the chapter on refraction, the observer will see the shadow play round the base of the cone, sometimes on one side of it and sometimes on the other, in a sort of crescent, so that the whole surface of the cornea is never evenly illuminated, and the shadow never crosses the surface in a definite line. In using the ophthalmoscope for the background of the eye, the observer soon discovers that he is looking through a distorting medium; and, although the position of the optic disc can be distinctly seen, the outlines, alike of the disc itself and of its vessels, will be indistinct, and cannot be cleared up by the intermediation of any lens. The observer looks into the eye, and the patient looks out of it, through a medium which may be roughly likened to the flaw left in a pane of crown glass by an air-bubble.

The tendency of conical cornea is to increase; and when the cone becomes so prominent that its apex is no longer effectually protected by the closure of the lids, the epithelium is liable to suffer, and the centre of the cornea may thus become cloudy or opaque. Before this condition has been reached, the vision is usually reduced to so low a point as to render the pursuit of any ordinary avocation impossible.

It is only within recent years that the treatment of conical cornea has been attended by any considerable measure of success, and this success has been due to the adoption, in various ways, of a suggestion first made by Albrecht von Graefe, who had observed the tendency of corneal ulcers to produce flattening of the membrane during healing, as well as by the subsequent contraction of the cicatrices which they left, and who determined to utilise this flattening for the purpose of restoring some approach to the natural outline. His first endeavours in this way were very tentative, and he made ulcers by scraping off the epithelium from a central patch of cornea, and by cauterising the exposed surface day by day until a sufficient effect had been produced. The ulcer was then permitted or encouraged to heal, and an artificial pupil was afterwards made behind that portion of the corneal periphery in which the natural curvature appeared to be most nearly restored. Other surgeons made their ulcers by excising the apex of the cone; and Sir William Bowman originated the plan of trephining the apex, in some cases removing the whole thickness of the cornea, in others only the superficial layers. Some hardy operators cut away an elliptical portion of the membrane, and united the edges of the resulting wound by a suture or sutures; but practices of this kind have not, on the whole, been justified by a sufficient measure of success to neutralise the manifest danger of wounding the lens, or of exciting destructive inflammation in the eye. Even when every precaution is adopted, the results, in many cases, are not brilliant; and it is necessary, in undertaking the treatment of conicity, to give a very guarded account of the benefits which are likely to be realised.

The experiments of Majendie, on the starvation of dogs, long ago made it known that the cornea, and especially the centre of the cornea, is very prone to suffer in its nutrition in all conditions of general weakness: and the subjects of keratoconus, as already mentioned, are in the great majority of instances girls or young women, suffering manifestly from anæmia or from some form of general debility. When such conditions exist, there is little temptation to proceed to operative treatment until they have been relieved;

and, when this has been accomplished, it is always possible that the further progress of the conicity may be stayed. In dealing with any case which does not involve incapacity for the business of life, it is first of all necessary to examine into the state of the general health, and to ascertain in what direction, and to what degree, it may admit of improvement; and, while the necessary treatment is being pursued, the conditions which favour the increase of conicity must as far as possible be avoided. These conditions, speaking broadly, are use of the eyes, or anything which calls upon the external ocular muscles for sustained or frequent action. Abstinence from eye-work should, therefore, be an essential part of the prescription; and, at the same time, a weak solution of sulphate of eserine should be instilled every night in order to diminish tension. A solution containing a quarter of a grain of the salt to an ounce of distilled water will be sufficient in most cases; and stronger solutions have the disadvantage of being apt to produce local irritation, which may require that they should be discontinued.

When all that is possible has been done in the foregoing directions, when any manifest defects in the general health have been amended, and when the eye has had a sufficient period of rest, it will sometimes appear that the further progress of the conicity is arrested, and that the patient may be able to make shift in life with such impaired vision as he may possess. In other cases, again, the conicity, and with it the impairment of vision, will manifestly increase month by month; or it may already have obtained a degree which condemns the patient to comparative helplessness; and, in either case, operative treatment is called for. The transparency of the corneal tissue, and the consequent invisibility of its internal boundary, render it impossible to ascertain the precise degree of thinning in any case, and this can only be judged of by the amount of the central projection. The greater the conicity, other things being equal, the thinner will be the centre of the cornea, and the greater will be the difficulty of removing a portion of its surface without opening the anterior chamber. An attempt in this direction should, I think, generally be made, and one of Bowman's trephines will usually be the most suitable instrument for the purpose. It should be carefully set to cut only to a depth which, in the judgment of the operator, will leave the membrane of Descemet intact, and the size selected must be governed by the magnitude of the cone. The pupil being first well dilated by atropine, and a circular incision having been made with the trephine over the apex of the cone, the surgeon seizes the edge of the circle with a pair of forceps, and peels it off from the subjacent tissue, the object being to leave a circular loss of substance, without an actual perforation. A solution of sulphate of atropine should then be applied night and morning, one containing two grains to the ounce being usually sufficient; and, on the second or third day, if the ulcer left by the operation does not appear to be deep enough to produce the required amount of contraction as it heals, the raw surface may be touched with a point of diluted nitrate of silver. Both the operation itself, and any subsequent cauterisation, may be accomplished painlessly by the use of cocaine; a wafer containing the fiftieth of a grain being introduced into the conjunctival sac twenty minutes before the operation, and repeated in ten minutes. For the subsequent cauterisations a single wafer will usually suffice. As soon as the surgeon is satisfied with the size and depth of the ulcer, it may be permitted to heal, the eye being closed by means of a pad and bandage, and atropine being instilled daily in order to keep the margin of the pupil away from any irritation which might otherwise extend to it. When healing is completed, the atropine and covering may be discontinued, and the cornea will be found less prominent, and sometimes restored almost to its normal curvature, its centre being, of course, the seat of an opaque cicatrix. The contraction of this cicatrix will be likely to continue for some weeks, and, until it is complete, it is useless to forecast the degree of the resulting vision. After a sufficient time the pupil may be widely dilated by atropine, and the surgeon should study the erect image of the background of the eye, in order to discover the part of the cornea through which the best and clearest definition can be obtained.

When this point is decided, the next step is to make an artificial pupil behind the selected portion of cornea, excising as little of the iris as may suffice to afford a sufficient opening, and making that opening a mere notch in the margin of the natural pupil. Some operators accomplish the desired end by first instilling eserine, and then drawing out the iris through a small wound made with a narrow knife, cutting off the portion which is grasped by the iris forceps, and returning the rest into the anterior chamber. I prefer the method which I devised some years ago, and described as "optical" iridectomy: that is, as an operation done solely for the purpose of affording or improving sight, and with no reference to the diminution of tension. The eye being

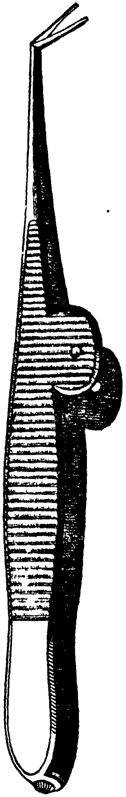

Fig 26.—Luer's Scissors.

cocainised and fixed, I introduce a narrow knife into the anterior chamber in such a way that its blade glides in front of the piece of iris to be excised, and then, withdrawing the knife with scarcely any loss of aqueous humour, I introduce through the wound a pair of Luer's scissors (Fig. 26), until their closed points reach nearly to the pupillary margin. The blades are then suffered to expand, and, as they do so, a minute fold of iris rises between them, and can be excised as they are closed and withdrawn from the eye along with them. The operation is one of considerable delicacy, but the chief risk attending it, that of wounding the lens, may be obviated by directing the points of the scissor blades well forward towards the apex of the cornea; and, after a little practice, the surgeon will find it possible to determine with considerable precision the size of the fold of iris that is excised, by allowing the scissors to include more or less of the membrane, accordingly as he desires to carry back the opening nearly to the ciliary margin or to spare it. However small a shaving of iris is excised, the opening will expand, as shown in Fig. 27, when the aqueous humour is again secreted; and, if the excised piece does not follow the scissors out of the eye, it may be seized by the careful introduction of a pair of fine forceps and withdrawn. Scarcely any irritation follows, and, in the great majority of cases, the small external wound heals rapidly. When the eye is again perfectly quiet, the visual results of the operation may be tested, and in most instances there will

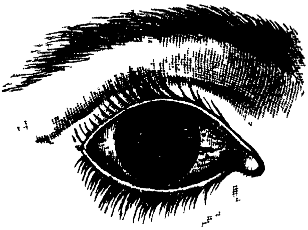

Fig. 27.—Optical Iridectomy.

remain enough of prominence or of irregularity for vision to be improved by carefully selected spherical or spherico-cylindrical lenses, adjusted as will be described in the chapter on Refraction. The final proceeding is to conceal the disfigurement produced by the central corneal cicatrix by tattooing it with Indian ink. For this purpose the eye should be thoroughly cocainised, the lids separated by a speculum, and a morsel of sponge should be held by an assistant against the outer edge of the upper lid so as to absorb any flow of tears, and thus to prevent the pigment from being prematurely washed over the general corneal surface. The operator finely drills the whole of the cicatrix with the point of a needle, and then, placing upon the portion thus treated some Indian ink reduced to powder, gently rubs it into the perforations with the flat side of a small wooden spatula. The superfluous pigment may be wiped away from time to time with a bit of sponge, so as to enable the surgeon to see exactly what has been done, and an endeavour should be made to blacken the whole of the cicatrix at a single sitting. If the procedure is nicely managed the cicatrix should be rendered inconspicuous, almost invisible, from the front, although it must of course be distinctly seen in profile. The tattooing should always be deferred until the contraction of the cicatrix is complete, so that it no longer contains any vessels which will yield red blood when punctured. When the little operation is finished, the eye may be bound up for a day or two, but a longer period of protection will seldom be required.

If the various steps of the operation for conical cornea are performed in the order indicated above, they will seldom be attended with any untoward results, although, in more than one instance, I have seen the lens become opaque during the healing of the cornea, especially when the central portion had been removed somewhat too freely. I have also seen an instance in which a surgeon commenced by an iridectomy, and afterwards attempted to produce a sufficient corneal ulcer by cauterisation of the apex of the cone with nitrate of silver. The application of the caustic, to an eye still irritable from the effects of a recent iridectomy, set up violent iritis, and occasioned so large a lymph deposit upon the anterior capsule that vision was practically destroyed.

When the lens becomes opaque during the course of the treatment, it may be removed, usually by suction, but at all events by some one of the methods which will be described in the chapter on Cataract.

The inflammations of the cornea range themselves naturally into three classes, accordingly as they tend to the development of vessels in or upon the membrane, to interstitial cell proliferation or plastic deposit, or to the formation of abscess or ulcer.

Pannus.—The forms of corneal inflammation which tend to the development of vessels are two in number, namely, that which is excited by the irritation of granular lids, and is called pannus, and true keratitis vasculosa. These forms are readily distinguished by the circumstance that, in the first, the vessels which traverse the cornea are quite superficial, are of considerable size, are visibly extensions of others which may be seen in the conjunctiva, and that they ramify over the cornea in a distinctly arborescent fashion, with intervals between the twigs, which thus form a sort of network, proceeding mainly from the upper portion of the membrane. In the intervals between the twigs the surface epithelium is generally more or less disturbed or cloudy, and the impairment of vision is proportionate to this disturbance. The amount and extension of the morbid change differs greatly in different cases, sometimes being inconspicuous, and hardly reaching to the pupillary region, while in other instances it may extend over the whole surface, and may be sufficiently dense to produce an impairment of sight which practically amounts to blindness. In all the cases, however, whether mild or severe, the vascularisation of the cornea is caused by the mechanical irritation produced by granulations within the lids, or by cicatricial thickening of the lining of the upper lid, left behind by severe, and possibly long past, conjunctivitis. As soon as the character of the case is recognised, the surgeon should evert the upper lid, and he will not fail to find an explanation of the mischief on its inner surface. Sometimes this will be covered with villous granulations, almost comparable to warts; sometimes these formations have disappeared, and have been replaced by hard cicatricial lines, which, by their contraction, have rendered the eyelid unduly convex, so that its inner surface is no longer perfectly applied to the surface of the eyeball.

In the worst cases of pannus, in which the cornea is so much covered by vessels as to be at best no more than semitransparent, and in which an abundant crop of fleshy granulations exists beneath the upper lid and in the tarsal fold, the best results have been attained by the artificial production of purulent conjunctivitis. The vascularisation of the cornea greatly diminishes, if it does not altogether take away, the risk of corneal sloughing which such conjunctivitis always involves; and, after the subsidence of the inflammation, the granulations often dwindle, and the cornea clears, to a very remarkable degree. In the earliest cases treated in this manner, the surgeon introduced into the conjunctival sac a drop of pus from a case of infantile purulent ophthalmia, and allowed the resulting inflammation to run its course with no other treatment than some soothing fomentation, and the removal of secretion from time to time.

It has recently been discovered that an inflammation of the required kind may be excited by the application to the conjunctiva of an infusion of the seeds of the jequirity plant, in the way already described on page 126. The ophthalmia induced by jequirity, although less severe than that induced by inoculation, is not wholly free from danger; and neither one nor the other should be used for any eye which appears to be at all within the reach of milder treatment, or in which any portion of the cornea retains sufficient clearness to admit of the restoration of even a moderate degree of vision by the formation of an artificial pupil. The beneficial results of artificially induced ophthalmia are only gradually obtained; and weeks, or, in some cases, even months, will elapse before the process of clearing which follows the inflammation can be said to be complete.

Another method of treatment, which also is very gradual in its operation, and which is suited to cases of the second order of severity, consists in the excision of the circumcorneal annulus of conjunctiva and of subconjunctival tissue, in order to starve the new vessels by separating them from their parent trunks, and to surround the cornea by a zone of firm and comparatively bloodless cicatricial tissue. This operation is called "peritomy," and is performed by dividing the conjunctiva as closely as possible to the corneal margin, and again in a wider circle around the former, and by dissecting off the strip included between the two incisions, using scissors and forceps, and stripping the exposed portion of sclera as bare as may be possible. The width of the strip removed should be in some proportion to the severity of the case, about two millimetres being perhaps a fair average; and, after the operation, the lids should be kept closed by a pad and compressive bandage, until the process of healing is far advanced. As in the artificially produced forms of inflammation, the subsequent clearing of the cornea is very gradual; but many cases in which, after even three or four months, little change has been produced, have undergone very decided improvement in the course of time, while the operation differs from purulent conjunctivitis in being wholly free from risk. I am not aware of any instance in which evil consequences have even been attributed to it, although the eye sometimes looks worse than before for a few days after the operation.

After peritomy has been performed, and when the circumcorneal region is consequently less lax and less vascular than in its former state, inoculation with purulent ophthalmia, or the application of jequirity infusion, is said to produce a less severe effect than it would have done when the conjunctiva was at its worst; and hence, in doubtful cases, in which the vascularisation is hardly sufficient to secure the cornea against necrosis as a result of ophthalmia, it has been the practice of some surgeons to perform peritomy in the first instance, and then, if its ultimate effects were not sufficient, to have recourse to the artificial production of ophthalmia at a later period.

The cases which require, or, indeed, justify, either of these severe forms of treatment, are by no means numerous, and are likely to become less so every year, as the treatment of the more acute forms of conjunctivitis is better understood. They are now chiefly furnished by persons who have suffered from ophthalmia in some remote colonial region, or in some barbarous country, or who have been among the victims of the epidemics of contagious ophthalmia which have visited certain workhouse schools. The army formerly supplied many of them[*]; but, with the improved education of military surgeons, this source is practically extinguished; and the majority of the instances of persons now met with in England are comparatively trivial, although even these are productive of much discomfort, and of disability for many forms of occupation. The lower half of the cornea is usually free from disease, but the characteristic arborescent distribution of blood-vessels exists over the upper portion, possibly encroaching upon, or even covering, the pupillary area, and the lid linings are rough or cicatricial. It is to these, and not to the corneæ, that treatment must be directed, and it consists in the persevering application of local astringents to the affected parts. The anæsthesia produced by cocaine not only greatly facilitates the treatment, but it permits the use of the best of all applications, a solution of nitrate of silver. A cocaine wafer having been inserted beneath the upper lid, and left for ten minutes, the lid is to be everted, and to be pencilled with a camel-hair brush barely moistened with the solution, which may generally be of the strength of ten grains to the ounce. The application being rendered painless by the cocaine there is no lacrymation, and no resistance or struggling on the part of the patient, so that the solution can be painted in a careful and leisurely way upon the places where its action is required, and is not carried to the cornea, or to any part of the surface where it is not wanted. The brush being only moistened nothing will trickle from it, and the smarting which, but for the cocaine, the nitrate would provoke, has time to subside before sensation returns. Such an application, carefully made daily or on alternate days, will bring about a more wholesome condition of the lid linings; and, contemporaneously with this change, the corneal vessels will gradually dwindle and ultimately disappear. In many cases, nevertheless, the cornea does not regain its pristine transparency and polish, and the remains of vessels may be visible for years, as fine dark lines, if looked for with a sufficient magnifier and adequate illumination.

Before the introduction of cocaine, the agent most relied upon for these cases was a stick of "lapis divinus" (Formula 14, Appendix D), used to touch the morbid portions of the lid lining. Its solidity prevented it from spreading to contiguous parts, but it was apt to occasion much pain, and may be entirely superseded by the above-mentioned way of applying nitrate of silver. Whatever agent is selected, the cases will require great care and patience; and, if they are dismissed from treatment prematurely, they will almost certainly undergo relapse.

Vascular keratitis.—The other form of inflammation of the cornea with formation of vessels, the true vascular keratitis, is one of the most severe and intractable forms of disease to which the eye is subject. It usually commences insidiously, with a small amount of intolerance of light and general uneasiness, some increase of tear secretion, and a little conjunctival redness. Contemporaneously with these symptoms, or soon after they appear, the careful observer will discover a small crescent of closely packed red vessels, bordering and encroaching upon the upper margin of the cornea. The vessels are too small to be individually distinguishable, even with the aid of a magnifier, but the crescent which they form may be seen, if looked at in profile, to be somewhat elevated above the general level of the corneal surface, and to slope down to this level by an abrupt declivity. Along the line of this declivity, and perhaps extending a short distance in front of it, will be a narrow band of epithelial disturbance, usually of a greyish colour; and, at the same time, a smaller crescent may frequently be discovered at the lower corneal margin, the two crescents presenting their concavities to the pupillary region, and advancing more or less slowly. As the vascular crescents increase in magnitude, they push before them the precursory bands of epithelial turbidity, until the latter, and sometimes even the vascular patches themselves, meet in the centre, and thus cover the whole of the corneal surface. This constitutes the form of inflammation which was described by old writers as causing the cornea to resemble "a ripe cherry, or a piece of red cloth;" a condition which has not often been witnessed since the complete abandonment of local astringents in the earliest stages of the affection. In such severe cases, the complete vascularisation of the cornea is usually attended by diminished tension of the eyeball; and, when at last the disease has run its course, and the vessels begin to dwindle, gradually receding from the centre to the circumference, they leave behind a peculiarly dense white opacity, almost as white and as dense as writing paper, which is only very slowly and with great difficulty absorbed. It begins to disappear first at the corneal circumference, where interchange of tissue is promoted by the neighbourhood of blood-vessels, and the zone of clearing slowly increases in width, until sometimes, after the lapse of months, or even of years, sufficient vision for guidance may be afforded by a lateral pupil. In the centre of the cornea, I have never, after a very severe attack, seen any important degree of clearing occur.

Vascular keratitis is chiefly met with in unhealthy or badly fed children, or in young adults; and chiefly, I think, in the female sex. It usually attacks one eye in the first instance, and before long, appears also in the other. I have seen a few instances in which the second eye was not attacked; but they are quite exceptional, and the ordinary course of events renders it desirable to warn the friends of the patient that the participation of the second eye is to be expected. The extreme gravity of the disease in bad cases is such that no example of it can be regarded without anxiety.

The peculiar anatomical character of this affection, the formation of the two opposite vascular crescents at the upper and lower margins of the cornea (I have sometimes, but very rarely, seen them a little displaced), points, it can scarcely be doubted, to perverted action of the nerves which govern the nutrition of the particular regions implicated. The analogy with herpes zoster is too evident to be missed; but I am not aware of any facts which assist us to localise the nerve lesion, or to assign to it either a central or a peripheral character.

The first canon of treatment is a negative one; namely, to apply no irritant. It would not be impossible for a careless observer to mistake the commencement of vascular keratitis for simple inflammation of the conjunctiva, and under this impression to prescribe a collyrium containing sulphate of zinc, or sulphate of copper, or some such substance, with the inevitable result that the disease would at once be roused into formidable activity. The only permissible local applications are soothing ones, among which the first place must be given to combinations of cocaine and atropine, and to warm fomentations to the closed lids. Both eyes should be protected from exposure to cold winds, to dust, or to glare; and all use of them in reading or other near work should be strictly forbidden.

The state of the general health and of the bodily functions will call for the most careful consideration. The urine should be examined with reference to the character and amount of tissue changes; and the state and regularity of the alvine evacuations should be ascertained. Inquiry should be made with regard to habits, appetite, regimen, sleep, and all other matters which may suggest themselves in relation to the individual case. If the patient be in poor circumstances, prompt admission into a hospital should be sought; and patients who are at ease with regard to worldly goods must be prepared for a tedious and troublesome affection.

There will be but few cases in which the first examination of the practitioner will not disclose the existence of some general condition which can be improved; and the first step in treatment must be to rectify whatever is manifestly amiss. Instances will occasionally be met with in which the administration of a few mercurial alteratives, together with protection from external sources of irritation, will be followed by speedy recovery.

After all general indications have been fulfilled, i no decided improvement is manifest, the medicin upon which I place most reliance is the perchloride o mercury, given internally in solution, either alone o in combination with iron (Formulæ 21, 22, Appendi D), and in doses ranging from the sixteenth of a grai to half that quantity, according to the age of th patient. At the same time, atropine and cocain should be applied to the conjunctiva, the eyes, if ther be much intolerance of light, should be completel covered by moist compresses, retained by a bandage and care should be taken to encourage feeding and t promote sleep. If the intolerance of light be trifling it will be sufficient to wear blue spectacles, more o less deeply tinted according to requirements; if it b very great, the bandage should cover a piece of blac silk, by which all light may be completely excluded.

In fine and warm weather, daily exercise should b taken out of doors, but in bad weather the patien should be confined to the house. In the latter even exercise should be taken with clubs, dumb bells, elasti bands, or by skipping, according to what is mo practicable in the particular instance. Few exercis are better than skipping; it can be done in a dark room, and it calls almost every muscle of the body into play.

As long as the turbidity precursory of the vascular crescents does not encroach upon the pupillary space, the sight will be scarcely, if at all, affected, and the case is only urgent on account of its possible developments. But if the increase of the crescents is at all rapid, so that the pupillary region is likely soon to be invaded, matters become very serious; and, in such circumstances, it has long been my practice to perform an iridectomy, introducing the knife into the anterior chamber in such a position as to cut off the larger of the two crescents from the sources of its blood supply. The general results of this method have, in my hands, been most satisfactory, although in a few cases it has failed to arrest the disease. As a rule, however, I have had no doubt of its great utility, and I could lay my hand on quite a number of patients in whom one eye was affected so severely as to call for iridectomy, while the other, less severely affected, recovered without an operation. In nearly all of these the eye operated upon, although always originally the worse, is now decidedly the better and more useful of the two.

In the cases in which I have performed iridectomy, I have been inclined to attribute its good effects chiefly to the incision, which would divide the channels of transmission of a possibly noxious nerve influence; and, in pursuance of this view, I have lately endeavoured to produce the same effect by the application of the galvanic cautery to the convex side of the crescent. My experience is not yet extensive enough to justify any positive statements, but the plan has certainly been sufficiently useful to deserve a more extended trial, and it offers the advantage of being applicable to both crescents at the same time. I have used a very fine platinum wire loop, and have burnt a shallow but definite groove immediately behind the crescent. The eyes have been fully cocainised, and the patients suffered no pain at the time, and very little when the effect of the cocaine had passed away.

In the clearly retrogressive stages of vascular keratitis, when all active irritation has ceased, and nothing remains but residual opacity, the use of local astringents need no longer be strictly forbidden. An occasional sprinkling of the corneal surface with dry calomel, or the application of a weak ointment (one grain to two drachms) of the precipitated yellow oxide of mercury, will often promote the diminution of the cloud. When the opacity is very dense, so as to cause blindness, an iridectomy, if not made previously, should be undertaken as soon as there is a zone of clear cornea of sufficient width to be available for the purposes of vision.

Inherited specific keratitis.—The most notable form of keratitis with interstitial cell proliferation or plastic deposit is that which has been definitively ranged by Mr. Hutchinson among the effects of inherited syphilis, and is commonly known as "inherited specific keratitis." The subjects of this affection are chiefly children, although in some cases its appearance is delayed until adult age, and then commonly appears to have been brought about by the influence of some depressing agency, awakening into activity a taint which had previously lain dormant. In typical cases, interstitial keratitis is associated with a remarkable combination of physical defects, the most conspicuous of which is a peculiar malformation of the permanent incisor teeth, more especially of the central incisors of the upper jaw. These teeth, instead of presenting the customary outline, have crescentic notches on their lower margins, and are bounded laterally by curved lines with their convexities outwards. Other of the incisor teeth, and in both jaws, are commonly malformed, but it is the malformation of the central upper incisors to which most importance must be attached. The other signs of inherited syphilis are that the bones of the nose are small and depressed, giving a concave or saucer-like aspect to the countenance, that the complexion is earthy, the general appearance somewhat senile, and that lines of radiating scars, the relics of intra-uterine ulcers, are to be seen about the alæ of the nose and the angles of the mouth. A common history in such cases is that the first pregnancies of the mother terminated in miscarriages, that afterwards a dead child was born at or near full time, and that then a living one made its appearance. The tendency of the syphilitic taint in the parent or parents is to exhaust itself; so that, when the first child born alive presents the above mentioned peculiarities in a striking manner, the next will often be less conspicuous for them, and they will diminish with each successive birth, until, if the lives of the parents are prolonged and they continue fruitful, there may at last be a child or children in whom no trace of inherited taint will be perceptible. It follows that the symptoms described above, as they are seen in extreme cases, may be much less strongly marked in others, especially in the younger children of a family, and that instances

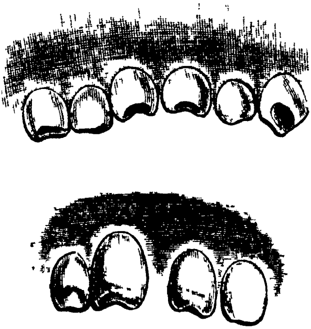

Fig. 28 —Syphilitic Teeth. (After Hutchinson.)

may arise in which the diagnosis may be doubtful. But, whenever the above-mentioned peculiarities are conspicuous, the children presenting them are liable to a special form of keratitis, and also to a form of deafness. The inherited specific keratitis comprises a large proportion of the cases which were formerly described as "strumous ophthalmia;" and it is a curious illustration of the possibility of being near to a fact, and of overlooking it, that the late Sir William Wilde, in a treatise on diseases of the eye which he published some five-and-thirty years ago, pointed out the great value of mercurial perchloride in the cases of "strumous ophthalmia" which were complicated by deafness, and yet, notwithstanding so striking a therapeutic indication of the nature of the affection, left this to be cleared up by Mr. Hutchinson many years afterwards.

As a rule, patients with specific keratitis do not present themselves to the surgeon until the disease has made some progress, and, when they come, the *facies* and the teeth generally point unmistakably to the nature of the disorder. But its characters have been so well described by Mr. Hutchinson, that they cannot be better stated than in his own words:

"Chronic interstitial keratitis usually begins as a diffuse haziness near the centre of the cornea of one eye. There is at this stage no ulceration, and exceedingly slight evidence of the congestion of any tunic. The patient, however, almost always complains of some irritability of the eye, as well as of dim sight. If looked at carefully, the dots of haze are seen to be in the structure of the cornea itself, and not on either surface; they are also separate from each other, like so many microscopic masses of fog. In the course of a few weeks, or it may be more rapidly, the whole cornea, excepting a band near its margin, has become densely opaque by the spreading and confluence of these interstitial opacities. Still, however, the greater density of certain parts, centres, as it were, of the disease, is clearly perceptible. Early in this stage the comparison to ground glass is appropriate. There is now almost always a zone of sclerotic congestion, and more or less intolerance of light, with pain around the orbit. After from one to two months the other cornea is attacked and goes through the same stages, but rather faster than the first. A period in which the patient is so far blind that there is but bare perception of light now often follows, after which, the eye first affected begins to clear. In the course of a year or eighteen months a very surprising degree of improvement has probably taken place. In milder cases, and under suitable treatment, the duration may be very much less than this, and the restoration of transparency complete, but in many instances patches of haze remain for years, if not for life. In the worst stage, the corneal surface looks slightly granular, and from the very beginning it has lost its polish, and does not reflect images with definite outlines. In certain cases, after the ground glass stage has passed, a yet more severe one ensues, in which the whole structure of the cornea becomes pink or salmon-coloured from vascularity, and in these, crescentic fringes of vessels are often noticed at its circumference. In the best recoveries, the eye usually remains somewhat damaged as to vision, and often a degree of abnormal expansion of the cornea is apparent. Only in one or two cases have I ever observed ulcers of distinguishable size on the surface of the cornea, and I have scarcely ever seen pustules on any part of it."

The treatment of interstitial keratitis does not materially differ from that of the vascular form already described. In the latter, as in the former, the careful avoidance of local irritants is the first condition of success, and attention to the general health, followed by the steady administration of perchloride of mercury, usually with iron and with cod liver oil, will conduct the majority of cases to a successful issue. If the eyes are subjected to irritation, either from improper local applications ignorantly prescribed, or from imperfect protection from cold winds, dust or strong light, phenomena much resembling those of vascular keratitis may become grafted upon the interstitial, and complications of a serious character, such as iritis, may arise. In a general way, the local treatment must be conducted with due regard to the requirements of the general health, and out-door exercise may be freely taken, the eyes being sheltered by blue or dark spectacles, or even by opaque pads, according to the intensity of sunlight and to the degree of intolerance. If intolerance should increase, and especially if it should be attended by tenderness in the ciliary region, the patient should be confined for a time to a dimly lighted room, and, if blood can be spared, a leech or two leeches may be applied to the temple or temples. The surgeon must remember that he is dealing with an essentially chronic malady, which will run a definite course, and will ultimately terminate in the restoration of at least comparative health, and that his business is to guide the course of events, to push the remedies which exercise some control over them, and to protect the patient from injurious influences. It is always prudent to warn the parents from the first that the case will be of long duration, and that the second eye will almost certainly be attacked.

The forms of keratitis which issue in the formation of abscess or ulcer are of very variable degrees of severity, and may lead to widely different terminations. Perhaps the first consideration may be given to the more trivial of them.

Phlyctenular keratitis.—More especially in delicate or strumous children, the cornea is frequently invaded by pimples which yield at their apices and produce small ulcers. These pimples appear to consist mainly of aggregations of lymph cells, which produce elevation of the epithelium and subepithelial membrane, and occasion pain and irritation, commonly associated with intolerance of light, probably by direct pressure upon some of the corneal nerves. The pimples are of the same character as those which are often met with at the very margin of the cornea, or on the conjunctiva, but are more important when they appear upon the actual corneal surface, on account of their liability to leave opacities, or small facets, in healing, and thus to interfere with the perfection of vision. At an early stage in the formation of the pimple, we commonly see a few vessels proceeding from the conjunctiva, and passing over the corneal margin in its direction ; and when the top of the pimple has yielded, and an ulcer has been produced, these vessels assume a still more definite form and direction, and constitute a fasciculus which conveys to the solution of continuity the materials for repair. It is not uncommon to see upon the same cornea the pimples in various stages of progress, some in course of formation, others ulcerated, others healed or healing ; and when this is so, it is necessary to recognise the existence of some constitutional cause for the affection. A single pimple, unless it be central, or at least sufficiently near the centre to interfere with vision, is a matter of very small importance ; but a tendency to recurrence must always be looked upon more seriously, inasmuch as the centre is likely to be implicated sooner or later.

The amount of distress occasioned to the patient by these corneal pimples, or, as some prefer to call them, phlyctenulæ, varies almost directly as the degree of intolerance of light which they occasion, and this again appears to depend partly, perhaps, on individual nervous sensibility, but chiefly upon the accidental involvement of corneal nerves in the ulcerations. The difference has often struck me as being somewhat analogous to that between different carious teeth, some of which will scarcely ever occasion pain, while others are sources of constant suffering. Some children with corneal pimples will open their eyes easily to light, and willingly permit examination, while others screw their eyelids together with all the strength they possess, hide their faces in the clothing of those who bring them, seek the darkest corners of rooms, and even assume strange bodily positions for the sole purpose of excluding light from their eyes. In such cases, when the lids are separated by the surgeon, a gush of tears previously confined within the rigidly closed lids, is usually permitted to escape.

The existence of such extreme intolerance of light, although it is by no means necessarily an evidence of great severity of the affection of the cornea, tends, as a matter of course, to its aggravation. The retained tears, and the pressure exercised by the spasmodic closure of the lids, are themselves active sources of irritation; and, until the intolerance of light is relieved, improvement in the state of the cornea is hardly to be expected.

In certain cases of this class, instead of the formation of definite pimples, we may sometimes see a more extended elevation of the corneal epithelium, generally near the margin, by a collection of lymphoid material, which may almost be described as a diffused pimple or phlyctenula. Such a collection may sometimes extend half way around the corneal margin, and may encroach perhaps for a line's width upon its surface. It is supported, so to speak, by an increased development of conjunctival vessels, and seldom ulcerates, perhaps because the distension of the tissues is nowhere sufficient to produce a strong tendency towards yielding. In such cases absorption of the material will often be brought about; but, in the presence of a definite pimple, ulceration is almost certain.

The first principle of treatment, in any case falling under the foregoing description, is to make a complete examination. With a child of sufficient age and intelligence, in whom there is no intolerance of light, or only a little, this may generally be accomplished by moderate coaxing; but if the patient is refractory, or too young to be reasoned with, or unable, on account of the intolerance of light, to open and guide the eyes effectually, an anæsthetic should always be employed, especially on the first examination. The surgeon, and the parent or attendant of the child, should sit facing each other on two chairs, and the latter, turning the child's back towards the surgeon, should lower its head between his knees, by which, with the intervention of a towel, it may be firmly grasped. The attendant should restrain the child's hands and body, and then, if necessary, the surgeon may administer a whiff of chloroform or of ether. Before doing so, he should take care to have within reach of his hand all instruments or applications which he is likely to require, so that he may avail himself of the anæsthesia for treatment as well as for examination.

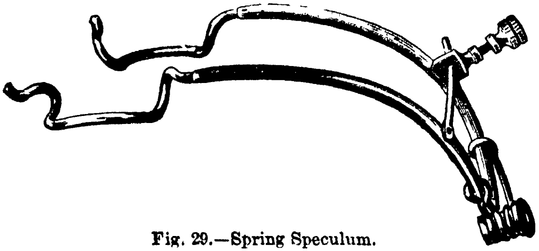

Fig. 29.—Spring Speculum.

The necessary insensibility being produced, it is generally desirable to separate the lids by a spring speculum (Fig. 29), and it is often necessary to control upward rotation of the eyeball by means of fixation forceps. The position chosen should be such as to permit good daylight or lamplight to be concentrated upon the ocular surface by a lens, while a second lens may be used as a magnifier, so that all details of the condition of the eye may be observed.

In cases of severe intolerance of light, especially if this has existed for some days and is not subsiding, it is often important to weaken the power of the orbicularis muscle. The strenuous and continued contraction of this muscle brings neighbouring skin surfaces into contact at the external canthus, and these surfaces, partly from sustained contact, and partly because they are kept moist with tears, assume somewhat the aspect of mucous membrane, and form a small red chink, continuous with the natural palpebral fissure, and appearing to continue it a few lines outwards. This chink has already been referred to on page 114, as occurring in the photophobia of catarrhal conjunctivitis, and it should be treated by division of some fibres of the orbicularis, as there advised. As a rule, the veins of the eyelids will be gorged with blood, the muscular contraction having arrested or much impeded the circulation through them; and the cut will be followed by rather free venous hæmorrhage, which will stop in a few seconds under gentle pressure from a cold damp sponge. The closed lids may then be covered by moist compresses, and the child should be put to bed as soon as possible in a darkened room. In a few hours the intolerance of light will generally have subsided in a marked manner, insomuch that the eyes may be examined without difficulty. The incision will heal without trouble, and will not leave behind any permanent weakening of the muscle, or any visible cicatrix.

When the intolerance of light is not sufficient to require recourse to myotomy, it may, nevertheless, be necessary to employ an anæsthetic in order to arrive at a diagnosis; and the conditions commonly disclosed in all such cases will be either an ulcer or ulcers upon the cornea, or the circumferential lymphoid deposit at its margin, with moderate general vascularity of the conjunctiva, and with increased vascularity at points corresponding with the ulcers or with the deposit. The vessels which run towards an ulcer may be regarded as contributory to its healing; but those which run towards an as yet unbroken pimple are the results of irritation. Advantage may be taken of the anæsthesia to place within the lids two or three wafers of cocaine, so as to secure local comfort for some time after recovery from the induced sleep, and, at the same time, the absolute ulcers may be touched with the point of a camel-hair pencil just moistened with a solution of silver nitrate, of five grains to the ounce of distilled water. The pencil should not be moist enough to apply the solution to any part but the actual solution of continuity, and the object of the application is to stimulate the healing of the ulcerated surface. At the same time, Pagenstechér's ointment should be prescribed as an application for domestic use, a portion the size of a large pin's head being placed within the conjunctival sac at bedtime, and suffered to diffuse itself over the ocular surface. In a severe case, or if only one eye is affected, a compressive bandage may be used to obtain quiescence of the lids, and to abolish the friction which they would otherwise exert over the ulcerated surfaces; but, if both eyes are affected, even badly, this plan should not be practised in any but cases of great severity, and should then be abandoned as soon as improvement has commenced, on account of the depressing effect upon the patient of loss of vision, and of inability to play about.

When the intolerance of light is not such as to forbid the eyes being opened, and when no anæsthetic is required for other reasons, it will usually be prudent to apply within the lower lid a drop of a solution of cocaine hydrochlorate, which may contain ten per cent. of the salt, and which is best made in a saturated solution of salicylic acid in distilled water. When this solution has been applied, it will usually be possible to insert a cocaine wafer without any sensation being produced by it; but if the wafer be applied in the first instance, it is felt as a foreign body before its sedative effect is produced. When the eye is completely insensitive, say in ten minutes after the introduction of the wafer, it may be examined quite readily, and the pencil carrying a silver solution may be applied in the manner indicated above. In such cases, however, the application may often be extended with advantage, and may reach not only the surface of the ulcer, but also the patches of conjunctival congestion in its immediate neighbourhood. Under the use of cocaine there will be no lacrymation, so that the liquid will not reach any point to which it has not been designedly applied by the surgeon. The Pagenstecher's ointment may generally be prescribed: and parents of sufficient intelligence and dexterity may sometimes be trusted to apply the cocaine and silver solution at home, and, in that case, to use it daily. When the requisite confidence in them cannot be felt, the surgeon should repeat the application himself, either daily, or alternate days, or at such increasing intervals as the progress of the case may indicate.

Until we possessed cocaine, the use of silver nitrate in these affections was greatly to be deprecated; and the power recently gained of using it with advantage forms a very considerable advance in ocular therapeutics. Without cocaine, the application would be very painful, so as to tax the fortitude even of an adult, and to be a certain cause of crying and struggling in a child. The flow of tears, caused partly by fright and partly by the agent, would carry the latter over the whole of the conjunctival surface, and would wash it out of the eye before its action on the specially diseased parts was complete. By the aid of cocaine, however, the use of the nitrate may not only be rendered painless, but can also be precisely localised to the spots where its action is required. Next in importance to the silver nitrate, I should place the Pagenstecher's ointment, which, if not too strong (it need only exceptionally contain more than half a grain of the yellow oxide to a drachm of ointment) would often of itself be sufficient to conduct a case to a successful termination.

While such is the local treatment, it is of the first importance that the constitutional treatment should not be neglected. The patient will usually be a more or less flabby and unwholesome looking child ; and it is the first business of the family doctor to ascertain whether it lives under any conditions by which its depressed health can be explained. The state of its sleeping room with reference to ventilation, and to the possible admission of sewer air, should be carefully inquired into ; the hours and character of sleep, the diet and appetite, the sufficiency of the clothing, and the state of excretions, should all receive a due share of attention. In all matters of regimen, conformity with sound hygienic principles should be insisted upon ; and it must be remembered that it is useless to stuff a child with food if its excreting organs are torpid or deranged, or to expect from it any great efforts of repair if its sleep is insufficient in soundness or in duration. An occasional mercurial alterative will often be indicated in these cases, and after its administration the appetite will frequently improve. When not forbidden by intolerance of light, plenty of outdoor exercise should be taken, but the patients should not be exposed to cold nor suffered to stand about, nor to remain in wet clothing, either upon their feet or their bodies. Delicate children often make difficulties about eating fat, and their nutrition often suffers for want of it; but it is worth remembering that they will almost always eat sausages, and that in this way a considerable amount of fat may be given under disguise. In the way of drink, I prefer bitter beer for such cases when they can be induced to take it; otherwise, a little Burgundy, perhaps diluted with Salutaris water. Either of these beverages will stimulate appetite, and, if sipped during dinner, will increase the amount of meat which can be taken. For the morning and evening meals boiled milk or weak tea is to be preferred, or cocoa made with milk; and Salutaris water, when thirsty, between meals. Plenty of sugar, stewed fruits, and ripe fruits in their several seasons, may generally be given with advantage.

On the subject of medicine it is manifestly impossible to do more than lay down general rules. Some one or more of the remedies commonly classed as tonics will frequently be required, and the surgeon will find that cod liver oil, with the various preparations of iron, arsenic, and mercury, will fulfil most indications. In some cases quinine is highly useful; and a night dose of bromide of potassium should generally be given when sleep is imperfect. I am sufficiently old fashioned to think that it is the duty of the practitioner to examine his patient and to prescribe for him, extemporising such combinations of drugs as may be best adapted to his requirements; and I always decline to allow my patients to be prescribed for by any of the ingenious persons who manufacture so-called "syrups" and other messes, containing, or professing to contain, a score or so of different ingredients, all of which are likely enough to counteract each other. It is, or at least it seems to me, in the highest degree slovenly to accept any manufacturer's compound syrup or solution of anything as a substitute for a prescription carefully planned to meet individual requirements. The sale of the preparations to which I refer, instead of affording evidence of the progress of pharmacy, seems to me to prove only the retrogression of the art of prescribing.

The results of the above described forms of ulceration, speaking generally, are only transient; for the lymph deposit constituting the pimple is situate immediately above the anterior limiting membrane, and beneath the epithelium, scarcely encroaching at all upon the true corneal tissue. It may be said, as a general rule, that loss of corneal tissue is never repaired except by an opaque cicatrix, but that losses of epithelium leave behind them only a temporary cloudiness, which, in the majority of cases, will ultimately entirely disappear. As soon as a superficial corneal ulcer is healed, the vessels which run to it from the corneal margin will begin to dwindle, and will speedily cease to be visible, although their situation will for a time be indicated by a faint cloud; and the scar of the ulcer itself, although visible for a somewhat longer period, will in like manner vanish in fulness of time. I much doubt whether any local applications are of real efficacy in promoting the removal of these superficial cicatrices when once the integrity of the surface is restored; but it is by no means uncommon to find that a succession of corneal pimples leaves undue vascularity of the conjunctival retro-tarsal folds, in which a tendency to irritation seems to linger when it has disappeared from all other parts of the eye. I have found advantage in bringing these folds under treatment with a view to the prevention of relapse, and am accustomed to apply to them a solution of silver nitrate after cocainisation, until they are restored to their natural appearance. When this is once accomplished, the title of "recurrent vascular ulcer," bestowed by some writers on the pimple ulcers under consideration, soon ceases to be accurate.

Snail-track ulcer.—Another form of vascular ulcer, which is of rare occurrence, but which may easily be mistaken for the foregoing by the inexperienced, is that which has been described as the "snail's track ulcer of the cornea." In this we find the solution of continuity, and the leash of vessels, but the ulcer is generally single, and its tendency is to proceed from the corneal margin towards the centre, healing on the marginal side and spreading on the central side, and dragging its tail of vessels behind it. The progress of the ulcer is indolent, and it does not extend to any great depth; but it usually implicates the corneal structure, so as to leave a permanent scar. It is seldom attended by much active irritation, but shows little tendency to heal. The aid of cocaine enables us easily to destroy its surface, either by scraping, by the application of a rather strong solution of silver nitrate, say of from ten to twenty grains to the ounce, or by the galvanic cautery; and any one of these methods will usually prove effectual if fairly carried out. One of them should be put in practice before the advancing extremity of the morbid process comes too near to the centre of the cornea, because the resulting opacity, which is of small importance as long as it is outside of the pupillary area, becomes a source of permanent disturbance to vision as soon as that area is encroached upon.

Punched-out ulcer.—Another extremely troublesome form of corneal ulceration is one which may frequently escape notice from the fact that it is not attended by any turbidity of the membrane. It occurs chiefly in children, and the patient usually complains only of slight pain in the eye, or of difficulty of using it at reading or work. On inspection, we at first see only a small amount of congestion, with some tendency to lacrymation; but if we get the light to fall at the proper angle, we shall see a depression in the cornea, looking precisely as if a small round piece had been punched or gouged out of its substance. There is no vascularity of the neighbourhood of the ulcer; no turbidity of its floor; there are no vessels running towards it from the margin. If we look straight at it, the ulcer may be invisible against the background of iris, and it then can only be seen by an oblique illumination. Its most frequent seat is near the corneal margin, and it seldom measures more than a millimetre, or a millimetre and a half, in diameter. Such ulcers seem to depend upon some disturbance in the nerves which govern the corneal nutrition, and they are often extremely obstinate. Direct local stimulation affords the best prospect of healing them, and may be applied in the several ways already mentioned, by scraping, by caustic, or by the galvanic cautery. When once the floor of the ulcer becomes turbid, or as soon as vessels begin to approach it from the margin, healing may be expected. In one obstinate case I at last succeeded in effecting a cure by adopting a method that was recently suggested, that is, by raising a small flap of conjunctiva in the neighbourhood, and by inserting the free extremity of this flap into the ulcer, the other extremity being left attached, so as to be nourished by its own vessels. The little graft adhered, the intervening bridge of transplanted tissue was in time cut away, and the woûnd in the conjunctiva gave no trouble. The scar was opaque for some months, but ultimately became scarcely visible.

While such are the chief forms of ulcer of the cornea which are met with in children, there are others more common in advanced life, and far more serious. These are the central ulcers which arise in the course of exhausting diseases, the ulcers produced by injuries, and those consecutive to corneal abscess.

Exhaustion ulcers.—When Majendie reduced dogs to a state of inanition by feeding them on gelatine, they nearly always suffered, for some time prior to death, from ulceration of the centre of one or both of the corneæ. It is not difficult to understand why this should be, the cornea being extravascular, and deriving its nourishment somewhat circuitously. The centre, as the part most remote from blood - vessels, would naturally be the first to suffer. In certain exhausting diseases this experience is repeated; and it is in this way that most of the cases of blindness due to small-pox are produced. It is not that a pustule forms on the cornea, but simply that the cornea undergoes necrotic ulceration from general debility. In diseases of a more chronic character the same thing is sometimes witnessed; and some of the most remarkable examples which have fallen under my notice have been in persons reduced by chronic dysentery. The patients have usually resided in some tropical country, and have returned home in the hope of recruiting their broken health. Pending this, the only treatment required by the ulcers may be summed up in the expression "rest and shelter." I have never seen both eyes affected; and my practice has been to keep the lids of the ulcerated eye closed by a pad of wool and a compressive band, so as to protect the weak membrane against atmospheric dirt, accidental foreign bodies, and eyelid friction, and to apply locally a weak solution of eserine, so as to render the ocular circulation more active by reducing tension. In one case, in which I feared the ulcer would perforate, and in which it had eaten so deeply into the corneal substance that the floor became prominent, I still further reduced tension by an iridectomy. In all the cases that I have seen the ulcers have healed eventually; and, in that last referred to, the iridectomy not only rendered good service in this direction, but also afforded good vision through the lateral pupil when the centre of the cornea was occupied by a dense cicatrix. It is worthy of notice that a strictly analogous form of ulceration, requiring similar treatment, is often met with during or subsequently to the occurrence of herpes zoster frontalis, an affection which is now known to be due to inflammation in the Gasserian ganglion, and in which the cornea manifestly suffers from the withdrawal or perversion of the nerve influence which controls its nutrition.

Sloughing ulcers.—The sloughing ulcers of the cornea, which commence by suppuration between the laminæ of the membrane, are mostly seen in aged and feeble people, often as consequences of some trifling injury, and are almost always highly injurious, if not fatal, to vision. If seen at an early stage, the seat of the suppuration is a greyish, irregular, opaque patch, over which the surface epithelium, although usually turbid, is unbroken, and by the side of which the iris can be seen to be unaffected. The eye is often acutely painful and tender to the touch, and vision through the turbid portion is limited to perception of light. In the course of a short time, the suppuration not only extends laterally, between the laminæ of the cornea, but also makes its way to the surface on both aspects of the membrane, leaving anteriorly a ragged ulcer, and permitting pus to escape, often by a track which can be clearly seen, into the anterior chamber.

The former of these conditions, in which the pus between the laminæ gravitates to the lower part of the cornea, was called by old writers "onyx," from a fancied resemblance of the collection to the lunula at the base of a finger nail; and the passage of pus into the anterior chamber constitutes the condition which has been known as "hypopyon." Unless the morbid process be speedily arrested, the ulcer increases both in depth and in superficial extent, so that it may soon cover the greater part of the cornea, and convert this membrane into a sloughing mass, while, at the same time, the presence of pus in the anterior chamber sets up iritis. The central portion of the sloughing cornea perishes, and then the iris falls into the resulting aperture. When perforation is complete, healing commonly commences, and the iris becomes covered with a film of plastic lymph, which ultimately closes up the opening, and thus in a sense replaces the cornea. To this lymph, however, the iris is, of course, adherent, so that there is no longer any anterior chamber; and the new material becomes stretched by the action of the muscles in movements consentaneous with those of the other eye, so that a staphyloma is produced. Vision is limited to perception of light, and does not admit of any improvement; but the eye sometimes quiets down, and gives no further trouble, while sometimes it becomes a perpetual source of pain, and of irritation and danger to its fellow.

The indications of treatment are obviously to limit the suppurative process, and to support the generally feeble powers of the patient.

The most potent medicinal agent for the fulfilment of the first indication is eserine, which has been the means of saving numbers of eyes, which, without it, must have perished. It appears to possess a power of checking the migration of white corpuscles, and thus of limiting the extent of the suppurative or sloughing process. A solution of the strength of four grains to the ounce may be employed in such cases as those now under consideration, and a drop may be inserted within the lower lid frequently; perhaps every four hours as long as the ulcer shows a tendency to increase. In a general way, alcoholic stimulants will be desirable, either in the ordinary forms, or as brandy and egg mixture, in quantities regulated by the actual state and the previous habits of the patient. Pain must be subdued if severe, usually by the subcutaneous injection of morphia; and hot compresses may often be applied to the closed lids with advantage, not only on account of their soothing influence, but also because they produce dilatation of the vessels, and thus contribute towards the increased vascular supply which constitutes one of the conditions of repair.

After a few hours of this treatment, if the process of destruction or necrosis is manifestly spreading, recourse should be had to iridectomy without further delay. The operation offers the twofold advantage that its performance, by evacuating the aqueous humour, produces the same tendency to healing that follows spontaneous perforation, and that the artificial pupil may provide for future vision by the side of the opaque cicatrix which, in the best of circumstances, must ensue. On this account the place chosen for the iridectomy should generally be behind that part of the cornea which presents the greatest width of unaffected tissue, that is, towards which there is the smallest extension of the ulcerative process. After the performance of iridectomy, the eserine may be discontinued, and nothing need be applied to the eye beyond simple compresses or warm fomentations.

If, when the case is first seen, the abscess has already perforated the posterior boundary of the cornea, so that pus is contained in the anterior chamber, the presence of this pus is almost certain to excite iritis, and, in such a case, the iridectomy should be performed without delay. The pus, which is often viscid, should be assisted to escape by gentle manipulation with a curette, and atropine should be applied as soon as the operation wound is no longer patent. In the face of any tendency to iritis, eserine would, as a rule, be inadmissible.

If the case be seen when the pus is still wholly confined within the corneal laminæ, so that the surgeon has to deal with a veritable abscess, the tissues in front of the pus should be very carefully divided to permit of its escape, and to check, in all probability, the tendency to a posterior perforation. The eye should be placed thoroughly under the influence of cocaine, which must be applied more freely and permitted to act for a longer time than would be necessary in the absence of inflammation, and an incision should be very carefully made across the suppurating patch with the point of a cataract knife. The treatment by eserine will then be as appropriate as if the front portion of the cornea had yielded spontaneously.

Ulcus serpens.—A form of sloughing ulcer, which can with difficulty be distinguished from that which follows abscess, has been described by some writers as *ulcus serpens*, or creeping ulcer, of the cornea. In this form, the process of necrosis commences on the surface instead of within the substance of the membrane, and spreads rapidly both in depth and in superficial extent. The ulcer is described as presenting a steep edge on the side of its advance, but this characteristic is not of much importance. Like others of the sloughing class, it tends to heal as soon as perforation has occurred; and Professor Saemisch has consequently advocated a plan of treatment by incision through its base. He introduces a Graefe's cataract knife, with its edge forwards, through the cornea on one side of the ulcer, brings it out by counter-puncture on the other side, and divides the bridge of intervening tissue, which consists of the floor of the ulcer, and of a slight margin of undisturbed corneal substance. The incision thus made is opened daily, with the end of a fine probe, until a general process of repair is well established, when healing may be permitted. The method is undoubtedly efficacious in its immediate results, although not more so, I think, than iridectomy; but I have found it very liable, indeed almost certain, to lead to adhesions between the iris and the cicatrix of the incision, and such adhesions have been fruitful sources of eventual trouble. In two cases I have been compelled by them to have recourse to enucleation, and I only mention the method in order to place on record my objections to its being adopted.

Crescentic ulcer.—Another form which is occasionally seen, chiefly in elderly people, and is apt to be troublesome, is one which excavates a narrow groove just within the corneal margin and concentric with it, so that, if it were to proceed unchecked, it would in time isolate the whole of the membrane from the more superficial sources of its nutrition, and might almost be said to trephine it. These crescentic ulcers are usually indolent, and are attended by little pain, so that they may escape notice until they have made considerable progress. When discovered, they are to be treated by rest and shelter, closure of the upper lid under a compress, eserine, attention to the general health, and, in obstinate cases, by cauterisation of the previously cocainised ulcerated surface by a solution of silver nitrate, carefully applied to the affected part in the manner already described.

Exceptional cases.—Besides the forms of corneal ulcer already described, the practitioner will occasionally meet with cases which hardly admit of classification, and which must be dealt with individually on their respective merits, and on the principles already laid down. Conditions affecting the general health must be carefully investigated, and made the subjects of appropriate treatment, and diet and regimen must be regulated. A tendency to corneal sloughing would demand the application of eserine, while much pain or irritability would demand atropine, and a high degree of vascularity would usually be relieved by cocaine, which may be combined with either of the preceding. In indolent cases a touch of silver solution, or a sprinkle of dry calomel, or a morsel of weak yellow oxide of mercury ointment, may be applied, usually in the first instance tentatively; and hot or cold fomentations may be ordered, the former to promote, the latter to restrain, vascular action. Pain should be controlled by cocaine or by the injection of morphia, and the closed lids should be restrained, by a pad and lightly compressive bandage, from exerting friction upon the ulcerated surface. As in all cases of serious affection of one eye, the use of the other upon near objects must be strictly forbidden.

Staphyloma.—In every case of extensive corneal ulcer, there will be liability to the formation of a staphylomatous protrusion in healing; and such protrusions, when extensive, or when formed of weak and yielding tissue, are often sources of pain and trouble, or even of danger, to the remaining eye. They are also in a high degree disfiguring; and, in a general way, they offer no hope of any restoration of useful vision. It is therefore right to sacrifice the mere perception of light which they may allow for the sake of obtaining relief from them. The best treatment of corneal staphyloma has called forth great differences of opinion and of method in former times; but the plan of dealing with blind eyes lately introduced by Dr.

Mules, that of clearing out the whole of the contents, and of filling the cavity of the sclera with a glass ball, appears to me to combine a larger number of advantages than any other. This operation is chiefly required in cases of injury, and will be fully described in the chapter in which these are dealt with; but I may say here that it affords a perfectly quiescent and painless stump, to which the external muscles retain their original attachments, and that this stump confers upon an artificial eye the power of moving in absolute harmony with the sound one.

Before dismissing the subject of corneal ulcers, it is necessary to lay down, as a rule to which there are no exceptions, that no preparation of lead should ever be applied to them. The salts of lead are excellent astringents and local stimulants, but they labour under the disadvantage of being liable to leave a deposit of the white carbonate on the surfaces to which they are applied; and, in the cornea, such a deposit may become covered in by epithelium, and incorporated with the eventual cicatrix. When this happens, it forms, of course, an indelible and conspicuous white patch; and this patch, after a time, usually cracks, and becomes a source of great mechanical irritation as a foreign body. When this occurs, the eye should be cocainised, and the whole of the lead deposit should be removed by careful scraping. The lids should then be closed for a sufficient time to permit restoration of the epithelium, and an excellent result may often be obtained. Another precaution which it is necessary to observe is not to apply calomel to a corneal ulcer while the patient is taking iodide of potassium internally, or the iodine in the system combining with the mercury, forms a biniodide, which is an active irritant.

Keratite en bandelette.—The cornea is occasionally liable to a form of turbidity, which might possibly be mistaken for a lead deposit, but which usually consists of calcareous matter, sometimes coloured by pigment, and secreted or deposited from the nutrient fluid of the part. The deposit is of very variable quantity and density, and is usually found as a horizontal band crossing the cornea, and occupying its superficial portions. It sometimes commences in the centre and spreads laterally; more often commences on both sides at the periphery, and gradually reaches the centre, where its presence takes away all useful vision. There is no customary English name for this rare affection, which is called by French writers "*keratite en bandelette,*" although it is not attended by any of the obvious characters of inflammation. The eyes in which it occurs are frequently the subjects of high tension, and may derive benefit from iridectomy; and several cases have been recorded in which the deposit has been scraped away with benefit. The recorded instances are hardly numerous enough for any rules to be laid down concerning them, and the affection rather belongs to the curiosities of ophthalmic surgery.

Staphyloma of sclera.—The anterior portion of the sclera, although it may be said to be continuous with the corneal structure, has but little tendency to participate in its diseases. It more frequently suffers in the chronic forms of inflammation of the ciliary region, or cyclitis, in which the sclera is prone to become softened, and then, yielding to the stress of intra-ocular pressure, to become stretched and elongated. In some cases of this kind it becomes staphylomatous, and it is from the protrusions of this region that the term staphyloma is derived. Certain fibres of the sclera retain their firmness, but the softened membrane yields between them, and suffers the pigmentation of the choroid to show through in such a manner that the projection is lobulated, and, as a whole, may, without extravagance, be compared to the appearance of a bunch of purple grapes. The treatment of the sclerotitis, before protrusion has occurred, is that of the inflammation of the ciliary region; and the protrusion itself is beyond treatment, being merely the remains of a pre-existing condition.

Episcleritis.—The tissues in front of the sclera, and between it and the conjunctiva, are liable to a peculiar form of localised inflammation which is called "episcleritis," or, in old books, "inflammation of the insertion of a rectus muscle." The characteristic sign of episcleritis is the formation of a lump of swelling, attended with more or less tenderness and pain, and with some congestion, in the neighbourhood of the insertion of one of the recti, generally either the internal or the external. The cases are very chronic, are most frequently met with in young women, and are aggravated by any kind of stimulating or astringent local application. The best treatment, after the rectification of anything manifestly amiss in the state of the general health, is the administration of small doses of the perchloride of mercury. A lotion of boric acid, containing four grains in the ounce of distilled water, will usually be the most useful local application. R. B. C.

CHAPTER V.

DISEASES OF THE IRIS.

THE iris, the general structure and conditions of which have already been described in the first chapter, is liable to be the subject of a congenital malformation called "coloboma," and may also be the seat of cysts or tumours of various kinds.

Coloboma of iris.—By coloboma of the iris is signified a deficiency of the lower part of the circle of the membrane, so that the pupil is of a balloon shape, or is an irregular ellipse with its major axis vertical. The defect is analogous to hare lip, since it implies the imperfect closure of the lower part of the infolded dermoid vesicle from which the eye is developed. A coloboma is sometimes a mere notch out of the margin of the pupil, sometimes extends quite up to the periphery of the iris, and, in the latter case, it may commonly be seen by the ophthalmoscope to extend also through the choroid, as far as to the entrance of the optic nerve into the eye. In some cases it is complete, in the sense that the whole thickness of the iris is wanting, from front to back, so that the deficiency is so much added to the pupillary aperture; while in other cases only the front surface of the iris is wanting, the deeper portions, with their lining of dark pigment, being present, and effectually preventing the admission of light, except through the portion corresponding to the natural pupil. Coloboma may be associated with other defects of ocular formation, but, standing alone, it is not incompatible with good vision, and may be of no importance except as a matter of appearance. It is wholly beyond the reach of treatment.

Cases of coloboma have been recorded in which the gap was situate in some other portion of the circle, but such cases are extremely rare, and the causes of their occurrence are not understood.

Pupillary membrane.—Up to a certain period of fœtal life, the pupil is closed by a fine membrane, the membrana pupillaris, which usually disappears prior to birth, but portions of which are sometimes permanent. Such portions may either be filaments crossing the pupil from side to side, and stretching as it dilates, or they may pass from the iris to the anterior capsule of the lens, and may be lost upon it. They may be distinguished from adhesions left by inflammation by the character that they originate on the anterior surface of the iris at some little distance from the margin of the pupil; but they are often so fine that they cannot be identified with certainty except by the use of focal illumination and a powerful magnifier. They do not appear to exert any influence upon vision, but they indicate imperfect development of the eye, and hence are most frequently seen in connection with hypermetropia or astigmatism.

Cysts of iris. — Cysts of the iris are of very rare occurrence, and are sometimes congenital, sometimes the results of injury. They may contain epithelial cells, and even hairs, or only a pellucid fluid, not distinguishable from the aqueous humour. In some traumatic cases a detached eyelash appears to have found entrance through the wound. However produced, cysts which are increasing in size are highly dangerous to the eye and an endeavour should be made to remove them without delay. When merely punctured or incised, they are not only apt to close and refill, but the evacuated contents often set up acute inflammation. The best treatment, therefore, as soon as such a cyst begins to increase, or to be troublesome, is to perform a large iridectomy, including the whole of the portion of the membrane invaded by the cyst, so as to bring out the latter entire.

When the cyst is very small, the operation presents no difficulties; but when it is large, perhaps coming into contact with the cornea, it is not easy to make the necessary incision through the ocular tunics without risk of wounding the cyst itself. This difficulty I have overcome by having the eye fixed for me by an assistant, and by making two punctures at once into the anterior chamber with two narrow iridectomy knives, held one in each hand, one puncture on either side of the cyst. Then, withdrawing both knives, I have introduced a Weber's lacrymal knife, which has a slightly curved and probe-pointed extremity, into one puncture, have glided it through the anterior chamber between the cyst and the cornea, brought it out at the second puncture, and then used its cutting edge to divide the bridge of intervening tissue. In this way a large external wound may be made, through which the cyst, and the portion of iris bearing it, may usually be coaxed without much difficulty. The necessary piece of iris is then excised, and the wound closed and treated in the ordinary way.

Tumours of iris.—Tumours of the iris may be dermoid growths, syphilitic gummata, sarcomata, or masses of tubercle; but the history and general aspect will usually serve to clear up any difficulties of diagnosis. A simple dermoid growth is likely to increase but slowly, and then by direct enlargement only, causing no symptoms but such as may arise from its bulk or pressure upon neighbouring parts, and occurring in patients who are in perfect health. Sarcomata of the iris are of rare occurrence, but they grow rapidly, not merely by increase of bulk, but also by multiplication, and by infiltration of adjacent parts of the membrane, but they are not usually productive of iritis until they have attained considerable size.

Between tubercle and gumma it is less easy to distinguish, both forms of disease presenting themselves as yellowish lumps or masses, and both being usually attended by iritis, the turbid effusions of which may obscure the characters of the tumours. The clue is generally afforded by the general state of the patient, since gumma only occurs, so far as I am aware, in the subjects of acquired syphilis, the evidences of which will usually not be far to seek; while tubercle is more likely to be found in strumous children.

As regards the general principles of treatment, any growth which may be either dermoid or sarcomatous should be excised, with the portion of the iris from which it springs, and without being itself subjected to any injury. The method of incision already described in the case of cysts may often be employed for tumours with advantage. Microscopic examination will then clear up the diagnosis, and if any of the characters of malignancy are discovered, it will be best, upon the first appearance of recurrence, either to remove or to eviscerate the eye, operations the details of which will be given under the head of sympathetic ophthalmia. A gumma is likely to disappear under anti-syphilitic treatment, leaving a more or less injured organ, and a mass of tubercle will frequently lead to degenerative changes. Neither of these forms of disease, however, will usually require operation, except as a matter of appearance, or will be likely to produce an extension of disease to the unaffected eye; so that they comparatively seldom call for surgical interference.

Plastic iritis.—The most serious form of disease to which the iris is exposed, because it is not only very common, but also very prone to inflict lasting injury, is what is called ordinary or "plastic" iritis. In this affection the inflamed membrane exudes a quantity of sticky lymph, which speedily unites the margin of the pupil to the anterior capsule of the crystalline lens, and the adhesions, or "synechiæ," which are thus formed may, if suffered to become permanent, lead on to destructive changes. The late Sir Thomas Watson, in his "Classical Lectures on the Practice of Physic," used the visible phenomena of iritis as illustrations of the similar, but concealed, phenomena of acute pleurisy; and between the course of the two affections, both plastic inflammations occurring in closed cavities, there is, indeed, a very close analogy.

The causes of iritis are exceedingly obscure.

Perhaps the one certain point about its history is that it often occurs as part of a general manifestation of syphilis, most commonly in its earlier, but sometimes in its later, stages; but it often occurs when syphilis is not present, and is often associated with the rheumatic diathesis. I think some writers go so far as to imply, if they do not exactly affirm, that it must be either "syphilitic" or "rheumatic;" and others, who have seen it in patients suffering under various diseases or diatheses, have used the several names of these as adjectives, and have discoursed learnedly of as many varieties of iritis as there are maladies in the nosology. They only mean that they have seen iritis occur under various conditions of illness or of health; and as long as this is clearly understood, all may be well. There is one ground, however, on which I strongly object to this ticketing of iritis with the names of various diseases; namely, that the habit is likely to mislead the inexperienced practitioner into an endeavour to treat the name on the ticket, while the iritis may be neglected until it has done irreparable harm. I do not know of any disease which prevents the occurrence of iritis, and hence I do not know of any with which it may not sometimes be associated. I have very little objection to its being described as "syphilitic," because the description is in many cases accurate, and because it has no tendency to interfere with, but rather to promote, the proper conduct of the treatment; but I do not know how to define the conditions under which the epithet may be properly applied. We see forms, or rather cases, of syphilitic iritis in which the local malady seems to be merely one manifestation of the general one, and these are clear enough. When we get beyond them, are we to describe as syphilitic every case of iritis which occurs in a patient who at any previous time has suffered from constitutional syphilis? If so, are we to assume that constitutional syphilis affords protection against all the non-syphilitic forms of iritis? If not, where are we to draw the line, and what symptoms or appearances are we to recognise in iritis as characteristic of a syphilitic origin? Many writers have laid down these symptoms and appearances, and there are books from the perusal of which one could rise with the belief that to distinguish between syphilitic and non-syphilitic iritis would be a simple and easy matter. A further examination shows that the syphilitic iritis of one writer is the non-syphilitic of another, and that the symptoms which one regards as pathognomonic are by another regarded as unimportant. When we turn to other diatheses or constitutional states, the confusion becomes worse confounded, and the practitioner, possibly not thoroughly skilled in the management of eye disease, but familiar with rheumatism or with gout, is not to be overmuch blamed if he is led by the "imposture and force of words" to attend to what he thinks he understands, and to neglect that about which he feels less confident. I strongly hold, therefore, that what I may call the diathetic nicknaming of iritis is to be deprecated. It does but darken counsel, and puts empty phrases in the place of knowledge. We do not understand a given case one whit better for calling it "rheumatic," and the term tends to relegate to the second place, as a mere accident of another affection, a malady in which all our skill will be necessary if we are adequately to discharge our responsibilities to the patient. No one attaches more importance than I do to a complete examination of every case which comes before us; and if we find syphilis, or rheumatism, or any other of the affections with which iritis may be combined, they should certainly be treated with care and diligence. But the iritis itself demands the first attention, and we must never fall into the error of supposing that, if the diathetic state can be relieved, the iritis may be left to itself.

Iritis varies greatly in the severity of its onslaught, being sometimes acute and violent, attended with much pain, congestion, and irritation, at other times slow and insidious, so that for a while it may easily escape notice. The eye may be a little flushed; the patient, if the other eye be closed, may discover that the vision of the affected one is a little dim. The more acute cases, in which the onset is sudden, the congestion considerable, the disturbance of vision marked, and the pain severe, should always be looked at from the point of view of glaucoma (which see), but, assuming no excess of tension to exist, the symptoms of iritis may be enumerated somewhat in the following order.

The congestion, whether it be more or less in the conjunctival vessels, always exists in a fine vascular zone, which immediately surrounds the cornea, in the sclera. This circumcorneal zone is composed of vessels which, even when distended in inflammation, are too small to be individually distinguishable, but collectively they form a pink circle or annulus, which is clearly subconjunctival, and which can be seen through the conjunctiva when the latter is not overfilled with blood. When there is much conjunctival congestion, the coarser vessels of the external membrane may completely conceal the delicate circumcorneal pinkness; but the latter will be disclosed by the simple expedient of pressing the lower lid against the lower part of the eye with the tip of a finger, and then suddenly sliding the lid downwards, so as to expose the corneal margin, while the finger pressure is maintained. This pressure, exerted against the firm eyeball, will empty the conjunctival vessels, but will fail to affect those of the sclerotic zone. The finger pressure will therefore leave a track of emptied conjunctival vessels, into which the blood will quickly return, but not too quickly to allow the observer to see whether the track is white with the pure whiteness of the sclera, or pink from the presence of a zone of circumcorneal congestion. The presence of the pink zone always indicates with certainty that tissues deeper than the conjunctiva are affected.

In a very small number of cases which circumstances almost accidental have enabled me to see from the beginning, the earliest symptom of iritis has been an obstinate contraction of the pupil, apparently neurotic or spasmodic, and resisting atropine. But the first symptom generally discoverable is a loss of the natural gloss of the surface of the iris, which looks somewhat dull when compared with that of the other eye; and there will always, I think, even at this early stage, be some impairment of vision. The patient may possibly be able to read quite fine type with the affected eye, but it will be less clearly defined than with the other. The pupil may still contract and expand under variations of light; but it soon becomes sluggish in its movements, and, at the same time, the loss of brightness of the iris becomes intensified by the effusion into the anterior chamber of yellowish serum, which alters the colour of all structures which are seen through it, rendering a blue iris apparently green, and a dark one dull and veiled-looking. Soon after this stage is reached, the effused lymph begins to form adhesions, and the pupillary margin becomes tied down here and there, so that its power of expansion is still further diminished. If atropine be now applied, it will act only upon the free portions of the pupillary margin, so that the dilated opening will be no longer circular, but will be fixed at one or more points, in a way which causes it to dilate irregularly, and to assume a form which may be something like that of the club on a playing card. (*See* Fig. 30.) When this appearance is seen, the diagnosis of iritis can no longer be missed even by the most inexperienced; although it may still be a question whether the adhesions are recent, or merely the evidences of a former attack which has passed away.

Speaking generally, iritis does not come under medical observation until its characters are no longer doubtful, that is, until the fluid in the anterior chamber is turbid, the vision much impaired, and the pupil irregular in outline. Sometimes, in addition to these conditions, considerable masses of effused lymph may be seen in the anterior chamber; and, in very severe cases, the iris is sometimes traversed by visible blood-vessels. The essential characteristics of the disease are, however, the formation of pupillary adhesions; and a case of apparently slight inflammation in which such adhesions have been suffered to establish themselves, may be just as disastrous in its ultimate effects, as one originally of far greater apparent severity.

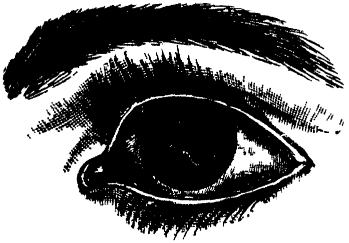

Fig. 30.—Iritic Adhesions.

The successful treatment of iritis turns entirely upon the possibility of preventing the formation of adhesions, or of overcoming them after they have been formed.

In a state of medium dilatation of the pupil, such as normally obtains in a moderate light, its margin lies in absolute contact with the surface of the capsule of the crystalline lens, the convexity of which projects through the opening; but, on account of the contour of the lens surface, the two structures are no longer in contact when the pupil is dilated, and the margin is then separated from the lens by the intervention of a stratum of aqueous humour. If lymph be effused in the former condition, when pupillary margin and capsule are in contact, adhesions will be formed immediately; but when the two structures are separated by the effects of pupillary dilatation, any effused lymph is dispersed harmlessly through the fluid, and no adhesions will be produced. Except in very severe cases, iritis tends naturally towards recovery. If the pupil can be kept fully dilated throughout the attack, this will, as a rule, die out harmlessly; but if dilatation cannot be maintained, adhesions will be produced, and, although recovery may be apparently complete, and vision may be restored to the normal standard, such adhesions will be likely, or almost certain, to lead to subsequent recurrences of the inflammation.

The chief function of the pupil is to vary in diameter with every variation in the quantity of light which falls upon it, so that its natural state is one of perpetual mobility. An adhesion, by checking movement at the spot at which it is situate, interferes with the proper discharge of this function, so that one part of the pupillary margin, or more than one when the adhesions are multiple, may be constantly checked and restrained in attempts at contraction and dilatation. Such checking and restraint become formidable sources of irritation, an irritation which differs in degree in different cases, but which probably reaches its maximum when one of the nerves of the iris is so situated as to be dragged upon. A cause predisposing to fresh mischief is always present; and whenever this cause is reinforced by depression of the general health, by exposure to cold, by fatigue of the eye, or possibly by other influences, the nature of which may easily escape detection, a fresh attack of iritis is liable to be produced. When this happens, the adhesion which has given rise to the inflammation serves also to aggravate its effects; for the part which is adherent cannot be dilated, and so removed from contact with the lens surface, but must stay where it is, with the result, in most cases, that the adhesion becomes broader, or that fresh ones are formed in neighbouring parts of the circle. Recovery may occur, to the extent that the eye may again become quiet, and that vision may be restored; but the adhesions left by the second attack prepare the way for a third, and this for subsequent ones, each fastening down another portion of the margin of the pupil, until at length the whole of this margin will be adherent, and the crystalline lens will form an immovable plug which fills and occupies the pupil, so that no fluid from behind the iris can pass into the anterior chamber to arrive at the filtration area. When this condition obtains, the pupil is somewhat awkwardly said to be "excluded," and the eye is on the high road to destruction. The retained fluid behind the iris, constantly increased by fresh secretion, and scarcely, if at all, diminished by exhalation, produces increasing pressure upon the interior of the vitreous chamber of the eye; and, under the influence of the secondary glaucoma thus induced, the structures essential to vision become involved in one common ruin. It sometimes happens, even in the presence of an adhesion, that a second attack of iritis does not occur; but, when once the habit of recurrence is established, unless this habit can be broken through, or its effects neutralised by treatment, the loss of sight will only be a question of time. Long before the pupil is completely closed, it is usually occupied, wholly or in part, by a film of lymph, by which vision, even when the deeper parts of the eye are sound, is necessarily much impaired.

A recognition of the serious consequences which follow from the formation of adhesions in iritis leads at once to the main principle which should govern the treatment of the disease. By the greatest attainable dilatation of the pupil, its margin must be kept out of contact with the surface of the lens capsule, so that adhesions may be mechanically prevented, and so that any which have already formed may, if not too tough and strong, be broken through; while, if the mydriatic agents in ordinary use are not of themselves able to accomplish what is desired, their operation must be aided and promoted by the administration of mercury.

The first canon in the treatment of iritis, as in that of keratitis, is the negative one to do no mischief. The cases, at a very early stage, are liable enough to be mistaken by ignorant or careless people for conjunctivitis, and, in consequence of such a mistake, to be treated by astringents. The most severe forms of iritis which present themselves at hospitals have usually this history. The patient had a "cold in his eye," and some druggist or other unskilled person gave him a lead or zinc lotion to apply to it. Such agents, which may be of high value in conjunctivitis, possess the property of aggravating iritis in an extreme degree; and hence they should never be prescribed, even for conjunctivitis, unless the prescriber has first made himself absolutely sure that the iris is neither participating, nor likely to participate, in the inflammation. If there be a shadow of doubt upon the point, the proper course is to let the astringent wait, and to prescribe atropine for a period of time sufficient to show the truth. I have seen many eyes which have been irreparably injured by neglect of this simple precaution.

Some years ago, when surgeon to the Royal South London Ophthalmic Hospital, I was long unable to account for the severity of a large proportion of the cases of iritis which applied there. A gentleman who was then clinical assistant to the hospital at length chanced to hear that a neighbouring public house had been founded, many years before, by a person who believed himself to be in possession of a specific for "bad eyes," and who was accustomed to give a little of his remedy to any customer who asked for it. The remedy was a zinc lotion, very admirable for simple conjunctivitis; and the giving of this preparation to customers became a tradition of the business, so that the house was largely resorted to by people with "bad eyes," who would take something to drink, and then put in a claim for the eye lotion. When this lotion was applied to a case of iritis, it never failed to aggravate its intensity in a marked degree; and this was the explanation of the circumstance which had perplexed me. The publican in possession at the time was a worthy fellow, who was shocked to discover how much mischief he had unconsciously promoted, and who, when the matter was fairly explained to him, readily undertook to serve out a weak lotion of atropine in place of the previous one. By adopting this plan, he preserved the custom of his house, and the hospital lost the cases of severe iritis, which had formerly been so numerous among the patients. It is not impossible that the new remedy may sometimes aggravate impending glaucoma; but the danger was not understood at the date when the negotiation was conducted. I am told that a well known firm of stationers are rivals to the public house in question; and that they give away an "eye lotion" containing lead to any person who applies for it before a certain hour in the morning.

The diagnosis of iritis having been made, the first step in the treatment is to effect, or at least to aim at, complete dilatation of the pupil. The best agent for this purpose, generally speaking, is a solution of neutral sulphate of atropine in distilled water, of the strength of four grains to the ounce. The lower lid being gently drawn away from the globe, so as to form a sort of pocket, a drop of the solution should be deposited in this pocket by means of a dropping tube, or of a quill cut to a blunt scoop. After waiting five minutes, a second drop should be applied in the same manner, and, after another five minutes, a third. This threefold application should be regarded as a single one, and should be repeated three times a day. If the case be seen early, if there be no increase of tension, only moderate pain, and not very much congestion, the atropine may prove to be the only medicament required. It may be persevered with for twenty-four hours ; and if, at the end of that time, the pupil is fully dilated, and quite circular, the surgeon may be content. The atropine should be continued, in single drops, once or twice daily, the patient should be sheltered from all injurious influences, and placed generally under conditions calculated to promote recovery, and the inflammation will die out harmlessly in the course of a few days. Quite recent adhesions will often yield to the dilating power of the atropine, and will be broken through, leaving on the capsule of the lens a series of little dark points showing where they had been attached. In a short time, the congestion will subside, the iris will recover its normal colour, and the patient may leave off the atropine and return by degrees to the freedoms of health. The period of such return, if incautiously managed, is apt also to be a period of relapse; and, on this account, requires to be watched carefully. The least reappearance of circumcorneal congestion should be the signal for returning to the regular instillation of atropine.

If, after the lapse of twenty-four hours, notwithstanding the employment of atropine in the manner described, the pupil is still irregular, showing that the adhesions are not inclined to yield, no time should be lost in the internal administration of mercury. The best preparation for the purpose is usually blue pill, in doses of two or three grains twice or thrice a day, according to the strength and constitutional condition of the patient. Such an administration of mercury, it must be remembered, has no relation whatever to the question of syphilis, but is called for by the iritis, whether this be syphilitic or not. The object to be aimed at is to obtain the therapeutic influence of the mercury without its poisonous effects; and the administration should be checked, or reduced to one dose daily, or on alternate days, as soon as the first line indicative of mercurial action is seen upon the gums. Coincidently with the appearance of this line, there will often be a marked amelioration of the symptoms, the eye feeling more comfortable, the congestion diminishing, the vision improving, and, not infrequently, the adhesions giving way. Whilst the mercury is being administered, the application of atropine must be continued without intermission, and in favourable cases we shall see the adhesions gradually yield to the combined effect of the traction and of the dissolving effect of the mercury, until at last they break and are released. As soon as every adhesion has yielded, the mercury may be laid aside; and if all appearance of inflammation has ceased, the atropine may be discontinued also; but if an adhesion remains unbroken, both the mercury and the atropine may be continued for as much as a month, care being taken not to push the mercury to excess. After the lapse of this time it is, generally speaking, hopeless to expect any further beneficial result; and the case must be looked on as having recovered with an adhesion or adhesions, which may require to be made the subjects of treatment at another time.

In some cases of iritis there is from the first a high degree of congestion, the superficial vessels of the conjunctiva being much distended. Whenever this is so, it is well to have recourse to local depletion, usually by a leech, or by two or more leeches, according to the condition of the patient. The leeches should be applied on the temporal region of the affected side, at about an inch from the outer canthus of the eyelids. If they are nearer to the eye than this they are apt to increase the local irritation. The application of a single leech may often be repeated with advantage.

In some cases complaint will be made of considerable pain, which may be either irritative, an effect of a high degree of nervous sensibility; or tensive, the tunics of the eye being stretched by a sudden increase of contained fluid. Great care should be taken to discriminate between these very different conditions; and the absence of excessive tension may always be determined by careful palpation of the eyeball, conducted as described in the chapter on glaucoma. When the pain is only irritative, the patient is generally of a neurotic temperament, and relief may usually be obtained by a dose of morphia, graduated according to age and general conditions, and which may often be best administered hypodermically. If there be high tension it may be relieved, at least for a time, by paracentesis; but if it should recur, it will usually be well to resort without delay to iridectomy.

The operation of paracentesis is a very simple one, and may be performed, by a skilful surgeon, with almost any instrument which has a point. For the benefit of those who are comparatively unpractised in such matters, there is a paracentesis needle (Fig. 31), an instrument with a sharp triangular point guarded by a shoulder, so that it cannot penetrate far enough to wound either the iris or the lens. The eye being brought under cocaine, for which purpose, during the existence of acute inflammation, a free application will be necessary, the operator pinches up, with fixation forceps, a fold of conjunctiva near the corneal margin, and opposite to the selected point of puncture, which, unless there be any special reason to the contrary, should be at the outer side of the cornea and on the horizontal meridian. The needle is then introduced into the anterior chamber at the corneal margin, and withdrawn as soon as it has entered the cavity. The other end of the handle carrying the needle is usually furnished with a blunt probe, which may be used to dilate the opening, and to press back its posterior lip until all the fluid in the anterior chamber has escaped. In some cases, if the former degree of tension is quickly restored, and if there is for any reason an objection to iridectomy, it may be desirable to reopen the puncture with the probe two or even three times in the twenty-four hours, so as to guard against the consequences of fresh accumulation. The high tension of iritis with excess of secretion seems to present an impediment to the absorption of atropine, and when the tension is relieved the pupil will often dilate rapidly.

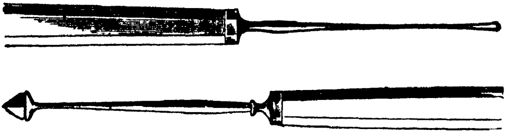

Fig. 31.—Paracentesis Needle and Probe.

In irritative pain, besides morphia and similar medicines, we have an exceedingly valuable therapeutic agent in cocaine, which may be used from the commencement in conjunction with atropine. Cocaine is best applied in the form of wafers, those of the British Pharmacopœia being, I think, too weak. They contain only $\frac{1}{200}$th of a grain of the drug, and a wafer containing $\frac{1}{50}$th is better suited for most purposes. Wafers are made which contain both cocaine and atropine, but I have no experience of their action, and hence prefer to employ the atropine solution in the way already described, and to insert a wafer of cocaine within the lower lid from time to time. It is not always, however, that the merely local anæsthetic will be sufficient, for although it may relieve the pain of the eye it may fail to lessen general irritability, or to produce sleep. Both local and general sedatives must be used as occasion may arise, and it may be laid down as a rule that pain must in some way be subdued. An inflamed eye is not likely to improve while it is painful.

If an iritis has been existing for some time, say for three or four days, before the patient seeks advice, and if atropine then reveals the presence of adhesions, these will generally be already too firm to yield to the action of the dilating agent alone, and it is best, in such cases, to lose no time before commencing the administration of mercury. Cases of this kind often present themselves at hospitals, and, unless admitted into the wards, will not be seen again for perhaps three days more. Mercury should be prescribed on the first visit, and may be laid aside at the second if the pupil is found to be released.

It has been already said that the patient must be placed in conditions favourable to recovery; and this phrase may be taken to include a variety of more or less obvious precautions. The affected eye itself should be sheltered, when out of doors, by a pad or compress of cotton wool, separated from the closed eyelids by a piece of soft rag, and so arranged as to exclude light and to secure immobility of the lids and uniformity of temperature. The use of the rag is to prevent any fibres of the wool from entering the palpebral fissure. All use of the sound eye (supposing one only to be affected) must be forbidden, in the sense that the patient must neither read, write, do needlework, or follow any handicraft. In severe cases, and in bad weather, confinement to the house is desirable; in mild cases, and in fine weather, it is proper to allow a moderate amount of exercise in the open air. Care must be taken to avoid wet feet, or chilling the surface of the body, and when in the house the eye must be protected against draught, heat, and glare.

I have already cautioned the reader against the well-meaning attempts of certain writers to draw the trail of a sometimes imaginary diathesis across the manifest phenomena of an obvious malady; but I do not in the least intend that any plain manifestations of a diathesis should be neglected or ignored. There is the iritis; and if the eye is to be saved from serious mischief the iritis must be the primary subject of attention, and must be treated as if neither rheumatism, nor gout, nor syphilis, had ever been heard of. But if the patient, besides having iritis, is also rheumatic, or gouty, or syphilitic, these conditions must also be made the subjects of treatment, so long as the iritis is not neglected on account of them. The chief difference likely to arise from syphilis would be a necessity for the continuance of mercury for a much longer time than would otherwise have been required. As for rheumatism or gout, the surgeon must examine not only the eye, but also the patient. He must ascertain the character of the renal and biliary secretions, the temperature, the state of the tongue and circulation, and must be guided, outside the iritis, by the several indications which these, or any of them, may afford. If the evacuations are deficient in bile, if the urine is of high specific gravity and loaded with lithates, these are circumstances which will suggest the use of appropriate remedies and appropriate regimen, but such remedies and such regimen must not be expected to cure iritis. It would scarcely be possible, within the limits of this treatise, to enter into details concerning the management of all the constitutional conditions with which iritis may be associated, and which must in every case be controlled by the general knowledge of the practitioner. It must be remembered, also, that this knowledge can in no way be more usefully applied than in guarding against the tendency to recurrence which, even apart from the influence of adhesions, hereafter to be noticed, is especially manifest when iritis occurs in persons of a rheumatic habit of body. In all such it is desirable to prescribe, after recovery, such a regimen and mode of life as may best keep the diathesis under control; and it is also desirable to regard the urine as a storm indicator, and to keep watch over its condition from time to time, for the purpose of anticipating any dangers of which it may give friendly warning.

When the eye recovers from the inflammation, and when vision is restored, it will sometimes be found that an adhesion remains, or even more than one; and the question how to deal with such cases often presents some difficulty. As long as there is an adhesion, there is a liability to the recurrence of iritis; and if recurrence once occur it is almost certain to occur again. Still, in a minority of instances it does not occur; and I know persons in whom portions of the pupillary margin have been adherent for years, but who have never had a second attack. The safest and best remedy against recurrence, and more especially against the disastrous consequences of recurrence, is iridectomy; but this operation ought not to be performed without clear necessity. Its action is, in the first place, to break the continuity of the circle of the iris, so that dragging upon the adhesions does not occur as an effect of movements responsive to changes in the amount of light; and, in the next place, by taking away the peripheral part of a considerable sector of the iris, it makes a permanent opening of communication between the anterior and posterior chambers, which no subsequent attacks of iritis, if such should occur, will be able to close up. In the great majority of cases it prevents any further recurrence; and where it fails to do this it prevents recurrence from setting on foot destructive changes.

Subject, of course, to reconsideration by the light of personal peculiarities, it is the best practice to leave an adhesion alone when it is the result of a first attack, and when the patient is remaining under skilled surgical supervision. Possibly the adhesion may do no harm, and, whenever harm arises, it can be promptly dealt with. But in the case of a patient who was departing from under skilled surgical supervision (going, for example, to any part of the world away from large cities), I should advise iridectomy on account of adhesions left even by a first attack. If there has been a second attack, and, still more, if there has been a third, I should deem it right to operate without unnecessary delay. I should then regard further recurrences as certain, and should think that the sooner the source of irritation was removed the smaller amount of damage would the eye be likely to sustain.

The portion of iris selected for excision is a matter of considerable importance. The necessary result of a partially adherent pupil, followed by the removal of a large piece of iris, is to leave an invariable opening of considerable size, through which light is freely admitted into the eye; and hence, on account of the inability of such an opening to contract when the amount of light increases, the patient will experience a certain amount of dazzling and inconvenience on going from a dimly into a brightly lighted place. In order to obviate this, the piece of iris excised should, whenever possible, be beneath the upper lid, so that this may easily descend and veil the artificial opening. A different practice is required in cases in which several recurrences have already occurred, and in which the natural opening of the pupil is so far occupied by a film of lymph as to be of little avail for visual purposes. It is then necessary to make an opening through which improved vision may be obtained; and a direction downwards and inwards is usually the best for this purpose. The positions directly downwards, directly inwards, downwards and outwards, and directly outwards, would next be relatively desirable in the order in which they are named. If any part of the margin of the pupil is free from adhesion that part should be selected for excision in preference to others, because, where the iris has been adherent and is detached by the operator, it usually leaves upon the lens capsule a certain amount of lymph and pigment, of themselves sufficient to form an impediment to the transmission of light through the newly-made aperture. As far as the main object of the operation is concerned, the prevention of future attacks and the formation of a wide opening between the anterior and the posterior chambers, one position for the iridectomy is as good as another.

After several attacks of iritis, it is not uncommon to find the iris stroma very weak and fragile, and adherent to the lens capsule over a zone of considerable width. In such cases the operator can seldom accomplish more than the removal of a small portion, leaving the pupil still occupied by lymph, and effecting little, even if anything, for the improvement of vision. In such cases the only effect of iridectomy will be to arrest destructive changes due to the retention of fluid behind the iris, and, when the eye has quieted down after the operation, the question of removal of the lens for the restoration of sight may be entertained in certain favourable cases.

It has lately been maintained, especially by some American writers, that the tendency of recurrent iritis is to die out, and that no operation is desirable for it. With this view I am unable to agree. I have watched cases in which operation was undesirable, or in which, for some reason, it was refused by the patient, for several years; and, although I have seen eyes hopelessly lost, I have not seen any in which cessation of the tendency to recurrence has occurred. But the operation, even when deferred longer than I should have desired, has in many instances been conspicuously successful. Occasionally, however, it does no good in old cases, and is followed by chronic irritation, which passes gradually into wasting of the globe.

When the influence of iritic adhesions in promoting recurrence was first clearly understood, many surgeons proposed to separate the adhesions themselves without removing any portion of the iris, a proceeding which has been called *corelysis.* The late Mr. Streatfeild, in London, and Dr. Passavant, in New Orleans, proposed operations of this kind: Mr. Streatfeild passing a hook round the adhesion, and breaking it by traction towards the centre of the lens; Dr. Passavant seizing the iris behind the adhesion by forceps, and using traction towards the periphery. One or other of these methods may be practised in special cases, particularly when the patient is a young woman with light irides, to whom an iridectomy would be a disfigurement; but they are less certain and more dangerous than iridectomy. They do not produce an opening of communication between the chambers independently of the natural pupil, and they are not free from the risk of producing traumatic cataract. In some instances the traction will tear the capsule of the lens instead of the band of lymph which is attached to it, and cataract will follow as a matter of course. Dr. Passavant's operation is also exposed to the risk of producing an adhesion between the periphery of the iris and the cicatrix following the puncture, an adhesion which may be concealed from view, and which may excite as much mischief as the one which it replaces.

"Serous" iritis.—Besides the "plastic" form of iritis, the membrane is liable to what has been called "serous" inflammation; and under this name two very different kinds of disease have been described by different writers. The name seems most applicable to a form of iritis in which the effusion fails in plasticity, and has little tendency to the formation of adhesions, being a turbid fluid, which distends the anterior chamber and forces the iris backwards. In this way we obtain an increased tension which is almost entirely due to pressure from over secretion in the anterior chamber, but which speedily affects, and for the time almost extinguishes, vision. This form of disease is rare, and occurs chiefly, according to my experience, in persons whose health is undermined by some serious constitutional malady, such as renal degeneration. The pupil is usually rather contracted than dilated, there is a good deal of tensive pain, and great impairment of sight. Mydriatics are of little or no effect, the tension of the eye preventing them from being absorbed. The proper remedy in such cases is paracentesis or iridectomy, the former being sufficient when the patient is near at hand, the latter being to be preferred when he is remote. I was once asked to see a medical practitioner in a distant part of England, the subject of renal disease, and found him suffering from such serous iritis as I have described. The anterior chamber was distended, the iris having a concave or saucer-like aspect, and its proper colour being obscured by the turbidity of the effusion. Vision was so far reduced that when I was standing at the foot of the patient's bed, he was barely able to see a white handkerchief held against my dark coat. I performed iridectomy immediately, and the tension of the eyeball was such that the moment my knife was loosened in the incision the contents of the anterior chamber spurted out in a jet. No other treatment was required, and the patient made a complete recovery, with the exception that his eye was permanently elongated from front to back by the distension it had undergone. The elongation was to the extent of a millimetre and two-thirds, insomuch that the eye, which had previously been emmetropic, was rendered myopic to the extent of five dioptres. The patient was a young man, and the distensibility of the sclera no doubt preserved him from complete blindness of the affected eye; for if the sclera had not yielded, the retina must have sustained serious injury. He lived for two or three years after the operation, and his state remained without alteration as far as the eye was concerned.

The phrase "serous iritis" has been applied, however, especially by German writers, to a very insidious and chronic form of inflammation, which affects not only the iris, but also the lining membrane of the cornea, and which is described in old books as "aquocapsulitis." This affection is said to be more common in women than in men, and to be liable to occur in the former about the climacteric period in a form unusually free from congestion. What may be looked upon as the corneal element in the disease has also been called "punctated keratitis," and is characterised by the deposit of some morbid material upon the membrane of Descemet in the form of a multitude of perfectly circular dots arranged in a pyramidal outline, the base of the pyramid being at the lower margin of the cornea, and the apex approaching or encroaching upon the region of the pupil. When looked at through the ophthalmoscope, the dots appear dark or black, but by focal illumination they are seen to be of a greyish colour, the shade differing in different cases. The dots vary in diameter, the smaller being usually at the apex of the pyramid, the larger towards the base. The circular outline of each dot, and the peculiar grouping of the whole, seem to point to some disturbance of the nervous control of the nutrition of the part as the cause of the affection. The iritis which accompanies the keratitis is of a very insidious character, attended by a slight zone of circumcorneal congestion, and occasioning single points of adhesion here and there. The disease is often associated with syphilis, but also occurs independently of it. I have seen it commence without any apparent cause in a man whose general health seemed perfectly good, and it sometimes follows other kinds of illness. One of the last instances which came under my notice was in a young lady who was just recovering from a severe attack of mumps.

The treatment of this form of serous iritis consists in rest of the eyes, attention to the general health, the maintenance of dilatation of the pupils, and the administration of some mercurial in small doses and for a long time. Atropine is generally the best mydriatic, and it need not be used in the strong solution advised for plastic iritis, a strength of one grain to the ounce being sufficient in most cases. This is not unimportant, because there are persons in whom atropine becomes a local irritant after a time, and the more readily, the more concentrated the solution. When this happens, its further use must be abandoned, and some other agent used in its stead.

Perhaps the most generally available is duboisin, an alkaloid furnished by an Australian plant of the order Scrophulariaceæ, the Duboisia myoporoides. Duboisin can hardly be distinguished from hyoscyamin, either by analysis or by its physiological effects; and it may be applied to the eye in a solution of its neutral sulphate of a strength of from one to four grains to the ounce. Its action is much more rapid than that of atropine, and its use is in some people followed by troublesome giddiness. Homatropia hydrobromate is another mydriatic which may occasionally be useful, although, for the treatment of disease, it is less available than others, on account of the brief duration of its effect. This, which is an advantage when all that is required is a dilated pupil for the purpose of facilitating some kind of examination, is as distinctly a disadvantage where the dilatation has to be maintained.

When atropine acts as an irritant, it not only produces flushing of the conjunctiva, but also redness and swelling of the skin covering the lids, especially of the lower lid. The redness is attended by a peculiar character of dryness, and by a feel to the finger resembling that of parchment, both of which are completely characteristic of the cause of the disturbance. The discontinuance of the atropine, and the application of a soothing ointment to the skin, will afford speedy relief.

Although, in all ordinary circumstances, iritis, even in its most acute forms, can be guided to resolution, it must be obvious that exceptions will from time to time be met with. Occasionally the disease early assumes a suppurative form, and spreads by continuity of structure to the ciliary body and choroid. Some cases of this kind, in all probability, are pyæmic in their origin, and such are met with in association with other developments of septic poisoning. In these cases the mischief may even commence in the choroid, and extend forwards; and it may lead to general suppuration of the eyeball. In other severe cases there is no actual pus formation, but the plastic inflammation extends to the deeper structures of the eye, involves also the anterior zone of the sclera, and, unless checked by treatment, ultimately terminates in wasting. When this occurs, the exudations formed in the choroid are liable to become converted into bone, and the shrunken eyeball is apt to be chronically tender, and in this condition may be a source of danger to its fellow. The subject of sympathetic ophthalmia will be discussed in a subsequent chapter, but it must be borne in mind that the transference of disease from one eye to the other, although most common as a result of injury, is also seen as a consequence of inflammation of undetermined origin. Since the experiments of Deutschmann upon the production of sympathetic disease in rabbits have rendered it at least probable that the channel of communication is by way of the lymphatics of the optic nerves, it has also become probable that many of the ordinary forms of disease in which one eye is first attacked, and the other, as a rule, a few weeks later, may be explained in the same way. Such a course, as has been already mentioned, is almost universal in interstitial keratitis, and also in some other forms of affection of the cornea.

R. B. C.

CHAPTER VI.

THE LENTICULAR SYSTEM.

Cataract.—The perfect transparency of at least the central portion of the crystalline lens is essential to good vision, and the various morbid conditions by which this transparency may be impaired or destroyed are comprised under the common appellation of "cataract." The word appears to have been employed to express an old belief that some kind of opaque veil had fallen behind the pupil; but it has now become so firmly established by long usage that it would be vain to seek to abandon it in favour of any more rational nomenclature.

In former times it was the custom of writers to divide cataracts into the true and the false; the former being those in which the opacity was seated in the tissue of the crystalline lens, the latter those in which it was upon the surface of the anterior capsule, as in opaque deposits left behind by iritis. The word cataract is now applied only to the former or true varieties; and deposits upon the capsule of the lens are described in accordance with their nature and causes.

The principal varieties of cataract are the "congenital," the "laminar," and the "senile." They are also spoken of as "hard" or "soft," but this division is liable to be misleading.

The crystalline lens, in childhood and youth, is of soft consistence throughout, and, as life advances, it undergoes a gradual hardening, which is more pronounced in the central than in the peripheral portions. The lens of a child, for example, can be reduced to pulp by slight pressure between the finger and thumb; while in the lens of an adult, although the outer portions would yield in the same way, the centre would offer a definite resistance. The lens of an aged person would be coated by a shell of soft material, but the greater part of its bulk would be distinctly hard. These facts are often expressed by describing the adult or aged lens as consisting of nucleus and cortex, but between these two portions there is no original or structural difference, and the proportion which they bear to one another is very variable. In some aged people the greater part of the lens will have undergone the hardening process, thus producing a large "nucleus" surrounded by a thin layer of "cortex;" while in others the hard part will be of small volume, and the soft or cortical part correspondingly thick and abundant. The words are convenient expressions of the facts so long as their true meaning is borne in mind.

When the lens undergoes senile degeneration, the retrogressive change usually commences at the deepest portion of the soft part or cortex, and extends from this deepest portion to the capsule, the nucleus in the meantime becoming harder and drier than before. The cortex passes through successive gradations of fatty change to absolute liquefaction, until, in the most advanced stage, the capsule may contain a milky fluid, within which a small hard nucleus sinks by gravitation. Such a cataract is commonly described as "Morgagnian," after Morgagni, by whom it was first described; but, in the present state of ophthalmology the arrival of this condition is in most cases anticipated by the surgeon, and a Morgagnian cataract is seldom seen unless when maturity has occurred in one eye while the other remained unaffected, so that no operation has been required.

Speaking generally, therefore, it may be said that all the cataracts of young patients are "soft," and that all the cataracts of old patients are "hard;" but those senile cataracts in which a small nucleus is surrounded by a comparatively large bulk of cortex are called "soft" by some writers, in order to distinguish them from those in which the nucleus is large and the thickness of cortex comparatively small. The distinction is of some practical importance, because it assists in determining the length of the incision necessary for the operation of extraction. All lenses in old people, however, are "hard" in the sense that they contain a nucleus which will not undergo absorption within the eye, and which cannot be extracted entire through an opening smaller than its own diameter; while all lenses in young people are "soft" in the sense that they may undergo complete absorption, and that they can be removed, by suction or other means, through a comparatively small external wound.

Congenital.—In congenital cataract, the lenses are usually so far opaque at birth as to give a milky whiteness to the pupils, and manifestly to preclude any better vision than the perception of light. An infant with congenital cataract will follow a flame with its eyes, but beyond the power to do this can have no vision. The cases are not common, and they appear to depend upon some grave error of nutrition during intra-uterine life, or, sometimes, upon the occurrence of intra-uterine inflammation. I have met with instances in which the lens tissue had undergone absorption, and the opaque capsules were adherent to the pupillary margins. Congenital cataract always calls for a very guarded prognosis, because the surgeon cannot be sure that he is dealing with an otherwise healthy eye.

Notwithstanding any doubts of this kind which may overhang the case, congenital cataract should always be removed by operation at a very early period of life. The external ocular muscles require the guidance of vision in order to acquire the power of fixation; and if an infant is born blind, and is suffered to remain so, the eyes will assume that condition of perpetual oscillation which is called "nystagmus," and which, even if vision should ultimately be restored, will greatly detract from its quality and usefulness. Whenever blindness exists during the first few months of life, whether from corneal opacities left behind by purulent ophthalmia, or from retinal or intracranial disease, or from cataract, nystagmus follows as a matter of course; and nystagmus can hardly be said to be at all within the reach of treatment. Hence it is important to remove any opacity from the axis of vision before nystagmus is established; and the operation should usually be performed when the child is about a month old, before it is called upon to pass through the troubles of vaccination or of teething. Unless the infant is in other respects well and thriving, a satisfactory wet-nurse should be procured before the treatment is commenced.

The healthy lens of an infant a month old is very soft, and, with the rapid interchange of tissue incidental to that period of life, would undergo speedy absorption if exposed to the action of the aqueous humour by the laceration of the lens capsule. The opaque lens is generally softer still, sometimes quite fluid; so that it can usually be absorbed without much loss of time, or may even be suffered to escape completely at a single sitting. The pupils should as far as possible be dilated, it being remembered that the irides of infants do not respond very readily to atropine, and that only a small quantity of a weak solution should be applied to their eyes, on account of the poisonous nature of the drug. I do not employ for this purpose a solution which contains more than one grain to the ounce, and it should be applied to the lower lid lining in small quantities by a camel-hair pencil, so as not to find its way down the lacrymal passages. A little chloroform should be administered, and, when the patient is still and in a good light, the eyes should be carefully examined by focal illumination. It will then often be possible to determine, by the appearance of the opacities, whether the lens capsules contain any coherent lens tissue, or only a milky fluid. Assuming the former condition to exist, the surgeon takes the finest possible cataract needle (Fig. 32), and passes it through the cornea on the outer side, and at about one-third of the distance from the margin to the centre. When the point is well within the anterior chamber, it is so depressed as to puncture the centre of the lens capsule, and may also be made to extend the puncture a little upwards and downwards, so as to cut a vertical slit, after which it should be immediately withdrawn. The flat sides of the lance-shaped point of the needle should look forwards and backwards; and this position should be maintained throughout the operation, and during withdrawal. There need be scarcely any loss of aqueous humour, and no dressing or covering will be required; anything of this kind being irksome to a young infant, and difficult to keep in place. If there be any attempt to rub the eye, the care of a good nurse, who will watch and restrain the hands, must be obtained.

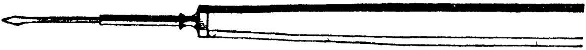

Fig. 32.—"Stop" Cataract Needle.

There will probably be no reaction, and on the day after the puncture it is usual to see a small piece of lens substance protruding through the rent in the capsule. This will be absorbed, and succeeded by another portion, and so on until, in the course of two or three weeks, the whole substance of the lens may have disappeared, perhaps leaving the pupil occupied by a film of opaque capsule. The application of atropine should be continued as long as absorption is in progress, and a careful examination should be made from time to time. This will seldom be practicable without the aid of chloroform and focal illumination.

Great care should be taken not to make the puncture in the lens capsule too large, lest the eye should be oppressed and irritated by the intrusion into the anterior chamber of too large a quantity of lens substance. It is possible, nevertheless, to make the puncture too small; and in such a case, or sometimes even when it has been as large as was permissible, it may close and reunite before absorption is complete. When this occurs, the needle must be used again; and on the second occasion it may be used more freely than on the first.

When the absorption of the lens matter is complete, the pupil may still be obstructed by a film of opaque capsule, the removal of which is as important as that of the lens. Chloroform should again be administered, and the surgeon should divide the film after the manner first suggested by Sir W. Bowman. A fine needle should be introduced through the cornea on each side, and the points of the two made to meet on the film in the centre of the pupil. The two points should perforate the film simultaneously, and the opening thus made should be enlarged by separating the needle points in such a way as to tear a central aperture in the film, but without any traction on the ciliary region. It is very easy to extract such a film by forceps, but the results of doing so are sometimes disastrous, the necessary traction producing inflammation of the ciliary region, which may easily go on to wasting of the eye.

When the contents of the capsule have become fluid, this fluid will escape as soon as the capsule is punctured, and will occupy the anterior chamber, concealing the iris from view. Its presence is likely to prove an active irritant, and it should be evacuated without delay. If the condition is ascertained prior to operation, the surgeon should employ the narrowest possible flat needle, with cutting edges, and then, if fluid escapes from the capsule in the manner described, he may enlarge the corneal wound by cutting with one edge as he withdraws the needle, so as to make a sufficient opening for the exit of the fluid from the eye. This exit may be promoted, when necessary, by pressing back the posterior edge of the incision with the extremity of a small blunt probe, as is done ordinarily in the operation of paracentesis.

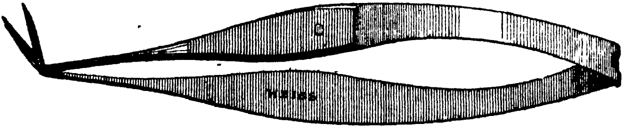

Fig. 33.—Carter's Capsule Scissors.

In the cases of congenital cataract which have followed intra-uterine inflammation, the surgeon will be likely to find, on introducing the needle, that the capsule recedes before it, carrying back the iris to which it is adherent, and being too tough and too little supported from behind to be readily punctured. It is then better to wait a few days for the puncture to heal, and the anterior chamber to refill, and then to perform a small iridectomy in a direction upwards, so as to expose the upper margin of the opaque capsule. A pair of capsule scissors (Fig. 33) may then be introduced, and the capsule divided vertically, the cut being carried so far down as to make a notch in the lower pupillary margin. A certain amount of retraction will be likely to occur; and, if this should be insufficient to afford a good opening, a further iridectomy, or a double-needle operation, may be done at a later period according to the requirements of the case.

The capsule scissors designed by the author, and shown of natural size in Fig. 33, may be introduced closed through a very small external wound at any part of the circle of the cornea, and they expand readily within the anterior chamber by the action of their own spring handles. They have a very fine and sharp-pointed posterior blade, which can be pushed through any capsular or other films in the pupil, and an anterior blade which is smooth and rounded at its extremity, so as to glide easily along the posterior surface of the cornea. They can thus be made to include any central opacity, and to divide it by simple closure; and their action may be limited to pupillary films, or extended, if the operator so desire, to the iris beyond them.

Laminar.—This form of cataract, which also goes under the names "lamellar" and "zonular," is probably congenital, but the degree of the opacity is neither sufficient to be conspicuous at birth, nor to become a cause of nystagmus. As a rule, laminar cataract is not discovered by parents at all, but the child will be said to be short-sighted, and will be accused of idleness and stupidity in the schoolroom. By the time it is eight or ten years old, some one will probably find out that the patient does not see as well as other children, and then advice will be sought.

On testing the vision of such a child, it will be found to read moderately small print with some difficulty, holding it very close to the eyes. Distant vision will be very defective, and will be scarcely at all improved by any glasses; at all events, will not be raised nearly to the normal standard. On examining the eye with the ophthalmoscopic mirror, it will be seen that the illumination of the interior is incomplete, and by focal illumination the lens will appear more or less mottled or clouded, the pupil not appearing black, but somewhat milky or grey. When the pupil is dilated, it will be seen, either by the ophthalmoscope or with focal illumination, that the central part of the lens is uniformly of imperfect transparency, while its peripheral parts are either transparent or are dotted with scattered points of opacity. If the permanent incisor teeth have been cut, it will generally be found that they present important departures from the healthy state. Their enamel is rough, of a bad colour, and has a worm-eaten appearance; while the tooth often becomes suddenly reduced in size at a few millimetres from its cutting edge.

The conditions thus described are due to the imperfect transparency of a single lamina of the lens, a condition traceable to defective formation during fœtal existence. The result is to produce a condition in which a clear nucleus is inclosed within a cloudy layer, and this is itself inclosed within a clear cortex. The basis of the permanent teeth is presumably laid at the same period; and the two structures suffer together. It is manifest, from the ring of transparent tissue around the opacity, that the latter does not reach to the periphery of the lens; and the uniformity of the opacity shows that it is limited in thickness. If the whole thickness of the lens were involved, the opacity would appear more dense at the centre than at the edges. The defect of sight is more manifest in looking at distant objects than at near ones, which, by being brought close to the eye, afford larger images. A deceptive resemblance to short sight may be thus produced, and may be distinguished from the reality by the failure of concave glasses to relieve it.

The treatment of laminar cataract is dependent partly on its density and partly on its diameter. If it be not very dense the patient, in certain circumstances, may see well enough to be content without submitting to operation; and, if it be of small diameter, it may be possible, either by maintaining dilatation of the pupil, or by operative enlargement of it, to afford vision through the clear periphery of the lens, so that sight may be improved and artificial lenses may not be required.

When the crystalline lens has been removed from the eye, there is no accurate vision of objects at any distance without the aid of an artificial lens; and there is no power of altering or adjusting the eye to fit it to the requirements of vision at different distances. Two pairs of spectacles are therefore necessary, one for near vision and one for distant objects.

Assuming a laminar cataract to be of small diameter, so that, when the pupil is dilated, the zone of clear peripheral lens matter is wide enough to afford good vision, without the help of a glass, it may be sufficient to produce and maintain such dilatation by the regular instillation of a solution of atropine. To this course there are two objections: the first being that atropine takes away the power of adjustment for near objects, so that for these spectacles would still be required; the second, that it is inexpedient to be dependent for vision upon the constant use of a highly poisonous drug, which, in some places, it might not be easy to obtain in a state of purity and efficiency, which, in some people, is apt to become a troublesome local irritant when its use has been long continued, and which, by the impediment which the iris, when the pupil is dilated, places in the way of the transudation of fluid from the eye, is always a possible cause of glaucoma. On account of these objections, it is generally preferable to enlarge the pupil in one direction by operation, so as to make a permanent opening for vision, to dispense with the use of atropine, and to leave the power of accommodation intact. The operation for this purpose may be undertaken in every instance in which good distant sight, with or without the aid of glasses, can be obtained when the pupil is fully dilated.

The object of the surgeon in such a case is to make the smallest notch in the pupillary margin which will suffice for the desired purpose; and it is manifest that the wider the zone of peripheral transparency the smaller the notch that will be required. The method of procedure which I have already described as "optical iridectomy," when speaking of conical cornea (page 137), appears to me to be the best which can be adopted; but an unpractised operator will perhaps act more wisely, and incur less risk of wounding the lens, if he employs eserine to produce contraction of the pupil, and then draws out, and cuts off with scissors, the smallest piece of iris that he is able to obtain. The piece excised should generally be in a direction inwards and downwards. In the case of girls it must not be forgotten, in estimating the relative merits of different procedures, that an artificial pupil, especially when there is a light iris, is a permanent and conspicuous blemish to the eye.

When laminar cataract is not very dense, so that, although entailing difficulties in seeing, it does not entirely prevent education or employment, there is something to be said in favour of leaving it alone. The point turns solely upon the degree of incapacity which it occasions in relation to the position and prospects of the patient, and the question whether to operate is one which parents must in such cases decide, after having been made fully acquainted with all the circumstances and bearings of the case. Their decision to have nothing done will sometimes be reversed by the patients, when these attain an age which entitles them to judge for themselves I have operated in several instances of this kind; among others upon a gentleman who, to please his father, remained purblind up to the age of forty, and to whom a new world has since been opened; and also upon a domestic servant, who found it difficult to keep a situation on account of her breakages, and whose experience as a hospital patient induced her to enter upon a course of training as a nurse, in which capacity she has been exceedingly successful. It must be remembered, however, that an operation for removal of the lens is beset, in adult age, by a somewhat greater risk than attends upon it during childhood or early youth.

Even if the diameter of the actual opacity be small, if the clear peripheral zone be itself at all dotted with opacities, a farther extension of these must be regarded as probable, and the excision of a portion of iris will, in such cases, be likely to prove little more than a temporary expedient. When, either for this cause, or on account of the density or the large diameter of the opacity, an operation for the removal of the lens is determined upon, in a patient under twenty years of age, the surgeon may rely upon finding the lens so soft that a cataract needle will penetrate easily through its entire thickness.

It was once the custom to treat these laminar cataracts by absorption after needle puncture, in the way already recommended for the manifestly congenital forms of opacity. With patients who are no longer in infancy, in whom the lenses, although not hard are firm, and in whom the active nutritive processes of early life have given way to the slower changes of youth, absorption is a tedious process, and is liable to be interrupted, if at any time too much lens matter finds its way into the anterior chamber, by attacks of inflammation, any one of which may prove destructive. In order to avoid the delays and dangers thus arising, it became a common practice to break up the lens at one sitting, and, after the fragments had been exposed for a few days to the softening influence of the aqueous humour, to coax them out of the eye along the groove of a curette. This practice was improved upon by the introduction, by Mr. Teale, of the old Persian method of removing the lens by suction.

By the use of cocaine, the operation by suction may be rendered painless; and, if the patient be a young adult, or a child of intelligence and courage, no other anæsthetic will be required. Much depends, however, on the exact performance of the necessary manipulations, and hence, if there be any doubt about a child's behaviour, ether or chloroform should be administered. The object is to divide the anterior capsule freely, to cut the lens into small fragments, and to avoid the posterior capsule, injury to which would admit vitreous into the capsular cavity. The pupil should be dilated, and two needles of perfect manufacture should be employed. By this is meant that their shafts should be absolutely cylindrical, and should bear such a relation to the size of their points as to move freely, but with a close fit, in the openings made by the latter, so as at once to retain the aqueous humour and to place no impediment in the way of a surgeon. The needles must be introduced through the cornea, near its inner and outer margin, on the horizontal meridian, one in each hand. The introduction of the needles may be facilitated, and the tendency to the escape of aqueous humour diminished, by coating them with a thin film of oil by means of the finger. The oil which I use for this purpose is a mixture of equal parts of olive and castor oils, to which 5 per cent. of eucalyptus oil is added. The needle introduced on the nasal side must be used to cut to pieces the temporal half of the lens; that introduced on the temporal side to cut to pieces the nasal half of the lens. Whilst one needle is being worked, the other should steady the eyeball, and the needles should execute a succession of parallel strokes so as to go through every part of the lens in order, and to leave nothing untouched; the depth and extent of the needle movement being regulated by the operator's knowledge of anatomy, so that the posterior capsule and the zonule of Zinn may be left uninjured. A solution of atropine should then be instilled night and morning, and the eye carefully watched.

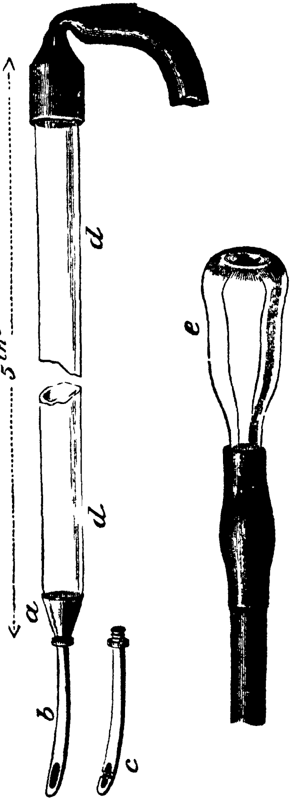

Fig. 34.—Suction Curette.

Soon after the needle operation (if this has been effectually accomplished) it will be found that the broken-up lens matter has become white and opaque, and that it occupies the anterior chamber, where it will increase in bulk from day to day, and will in time become a source of irritation. When the eye remains quiet, it is desirable to defer the next step for a week, in order that the softening of the lens matter may be complete;

but the occurrence of pain, or the appearance of a zone of circumcorneal congestion, must be taken to indicate that the time for further action has arrived. The next thing is to remove the softened material by suction.

The best instrument for this purpose is the so-called "suction curette" (Fig. 34), a slender silver tube *b c*, about an inch long, which receives by a bevelled shoulder *a* one extremity of a somewhat larger glass tube *d d*, about four inches long, which serves both as a handle and as a receptacle for whatever may be drawn out of the eye. This tube is continued by another of indiarubber, about a foot long, which terminates in a glass mouthpiece *e*. Unless a new suction curette is used for each operation, care is necessary in order to prevent the instrument from becoming a means of septic inoculation. The silver and glass portions are cemented together by a solution of shellac; and hence the curette cannot be washed in hot water without these parts falling asunder; while, if it be washed in cold water only, fragments of albuminous matter in a state of change are likely to be left in the small calibre of the silver portion, and thus to be conveyed into the eye. On this account an instrument which has been previously used should be soaked in diluted Condy's Fluid for some minutes before the operation; and may be blown dry and wiped at the time when the surgeon is ready to take it in his hand.

The silver portion of the curette is a tube semicircular in section, the flat side of which is intended to be turned forwards, or towards the cornea, the convex part towards the posterior aspect of the eye. The orifice for the admission of lens matter is situate at the extremity of the flat surface, is oval in shape, and should be prolonged on either side by a notch, shown at *c*, sufficiently deep to prevent it from being closed by contact with the posterior surface of the cornea. A speculum being placed between the lids, and the surgeon having the mouthpiece of the curette between his lips, and the glass tube ready to his hand, he makes an incision through the cornea near its margin, with a small iridectomy knife or broad cutting needle, and then, withdrawing the cutting instrument with the least possible loss of aqueous humour, immediately inserts the curette, holding it by the glass tube and carrying the extremity of the silver tube rather deeply into the space which the lens normally occupies. This is important, because suction is much impeded if the matter to be sucked out is behind the curette aperture, instead of being in front of it; and I have more than once seen the proceedings of an operator greatly hindered by his tube being too close to the posterior surface of the cornea. At the same time, great gentleness of manipulation is required in order not to thrust the extremity of the tube through the posterior capsule into the vitreous cavity.

In ordinary cases, if the breaking up of the lens has been sufficiently complete, and if the fragments have been exposed for a sufficient time to the action of the aqueous humour, the whole of the lens material will enter the tube readily by very gentle mouth suction, and a clear black pupil will be left. The curette may then be withdrawn, and an ordinary dressing applied.

If the use of the needles has been imperfect, so that the fragments left were too large, or if, from the appearance of signs of inflammation, suction is called for at too early a period, it will often happen that something will be left behind. Carefully watching his own proceedings, the surgeon will sometimes be able gently to follow a rebellious fragment with the curette, and at length to capture it; sometimes portions of lens matter, which are not yet opaque, and are too viscous to enter the aperture readily, will escape both his instrument and his observation. In cases of the latter kind, the removal of the bulk of the material will usually suffice to diminish any irritation which may have been commencing, and the lapse of a few days will allow the suction to be repeated, and to be carried to a successful issue. The only after treatment required will be the maintenance of dilatation of the pupil by atropine, the closure of the lids for a few days, until the external wound is securely healed, and protection of the eyes from dust, glare, or other agencies likely to be injurious to them. When otherwise perfect recovery has taken place, it will sometimes happen that shreds of capsule may remain in the pupil as impediments to vision, and these may be put aside by the employment of two needles in the manner already described. A successful suction operation should leavo a circular and movable pupil, and should afford, with the aid of any required lenses, complete restoration of vision.

Since using Condy's Fluid for the curette in the manner described above, I have not met with any instance of serious complication. Prior to adopting this practice I saw two cases in which acute inflammation, apparently of a septic character, followed the act of suction. In one of these cases, in consequence of the temporary closure of St. George's Hospital, the patient was transferred to another hospital, where he lost his eye, which was ultimately enucleated. In the second case, the inflammation was arrested by a large iridectomy and the complete evacuation of the contents of the anterior chamber, and the patient recovered with good vision.

Senile.—The third and most common form of cataract is the "senile," which is an opacity of the lens depending upon the occurrence of changes incidental to the decline of life, but which, without manifest derangement of the general health, occur at a much earlier age in some persons than in others. The commencement of senile cataract is seldom seen before the age of forty, and is not uncommon after sixty-five or seventy. Successful operations have been performed upon centenarians, and between the ages of eighty and ninety good results are constantly obtained.

It has been already mentioned that the lens naturally increases in hardness as life advances. At the same time, it acquires a yellowish or amber tint, which, in some people, passes into dark brown. It is quite possible for vision to be impaired, and especially for the perception of colour to be affected, by mere yellowness of the lens, without the occurrence of anything that could be strictly called opacity. When an elderly person complains of defective sight, cataract may generally be expected, and should always be looked for. The patient will frequently state, or will admit upon inquiry, that he sees better when his back is turned towards the light, the explanation being that the dilatation of the pupil gives him a larger area of turbid lens to see through. It will often be found that distant vision is somewhat improved by weak concave glasses, the changes in the lens which have diminished its transparency having also increased its refracting power, so that a small degree of short-sight is produced. No mere appearance of milkiness or cloudiness of the pupil, as seen by ordinary inspection, must be relied upon; such appearances being often entirely deceptive; and the only way of arriving at a certain diagnosis is by the use of the ophthalmoscope and of focal illumination. Using the ophthalmoscope mirror alone, or preferably with a strong convex lens behind it, and approaching to within the focal length of this lens, it will be seen that the pupil no longer presents a circle of unbroken illumination, but that it is interrupted by dark lines or spots, which are sometimes irregularly distributed in or near the centre, more frequently arranged as radii, each one thicker at the base and tapering towards the apex, the latter being directed towards the centre of the pupil. When the ophthalmoscope is laid aside, and focal illumination is employed, the lines or spots are seen to be of a greyish colour by contrast with the darkness around them. In order to complete the examination it is necessary to notice the mobility of the pupil, to test the lateral extent of the field of vision, to feel the tension of the eye, and to make a mental comparison between the degree of impairment of sight and the extent and density of the opacities. If the impairment is not in excess of the degree of opacity, and if the eye is in other respects healthy, the case may be pronounced to be one of simple cataract, and a favourable issue may be predicted when the time for treatment arrives.

The nature of the changes which occur in the lens have been studied by several observers, and it is said that, at a certain period of the process of hardening heretofore described, an actual separation (a solution of continuity) occurs between the nuclear and the cortical portions, these being at first separated here and there by the formation of gaps or vacuoles. As a result of this process, the cortical portions lose their transparency, at first in lines or dots, and afterwards throughout, and ultimately pass through fatty degeneration into a liquid condition. The nucleus, in the meanwhile, becomes drier, browner, and more hard.

As long as the most superficial layers of the cortex retain their transparency, the cataract is said to be progressive; but, as soon as the opacity reaches the surface of the lens, the cataract is said to be "mature." This distinction is of importance from the point of view of the operator, although it is less insisted upon now than it was in former years.

When cataract is mature, the pupillary circle appears of a greyish or bluish white, and the lens is often mottled or striated in a manner suggestive of spermaceti, or of unpolished opal. If light be thrown upon the eye from either side, the margin of the pupil, being in absolute contact with an opaque surface, casts no shadow upon it; whereas, if there be any layer of transparent tissue still intervening between the opacity and the capsule, the margin of the iris will cast upon the former a crescentic shadow of a breadth proportionate to the thickness of the transparent material. In complete maturity, again, the ring of dark pigment which surrounds the pupil becomes conspicuous against the light-coloured surface of the cataract; while, if there be any intervention of transparent tissue, the dark line is hardly perceptible. In many cases, when the layer of opaque cortex is not too thick, the amber colour of the nucleus within can be clearly displayed by the aid of focal illumination.

If a patient with cataract seeks advice when the lens is still sufficiently transparent to allow an ophthalmoscopic examination of the fundus, this must never be omitted, and must be made completely and carefully on account of the light which it may throw upon prognosis, and because the opportunities for it may not long exist. The surgeon will sometimes discover retinal changes of such a kind as to leave but slender hope of the ultimate restoration of sight by operation.

If the patient does not apply until the cataract is mature, or nearly so, or, at all events, until it forbids any sufficient examination of the fundus, the following points must be regarded: Opacity of the lens neither destroys the perception of light nor diminishes the extent of the field of vision. In a case of uncomplicated cataract the patient will be able to point out the position of the window, and his pupils will act promptly and naturally to light. He will discover the passage of a hand between his face and the window, although he may not be able to count fingers. He will be more likely to do this if his back is turned towards the light, and if the fingers are so held as to be fully illuminated by it. When a small lighted taper is held before him he should at once recognise the position of the light, and he should discover the presence of a second lighted taper held within a few inches of the first. One of these tapers being stationary, and his eye being fixed upon it, the other should be moved over the field of vision in all directions, more especially towards the nasal side of the eye, and should be seen in each direction over the natural extent. If these tests are passed satisfactorily, a favourable opinion may be given without reserve.

If the perception of light be defective; if the field of vision for light be broken or irregular; if there be any history of antecedent ocular disease; if the tension be either too high or seriously diminished, a very guarded, if not an unfavourable, prognosis will be called for. If the eye be too hard, and if the field of vision be contracted on the nasal side (*see* Glaucoma), it will generally be expedient to recommend the preliminary performance of iridectomy, and that the treatment of the cataract itself should be deferred.

It is also necessary, in all cases, to examine not only the eye itself, but also the state of the general health. Cataract, especially when it occurs comparatively early in life, is sometimes associated with glycosuria; and this, although it does not forbid operation, yet compels doubt as to both the character and the permanence of the result.

Cataract is so purely a degenerative change, that its arrest, by any kind of medical treatment, seems hardly to fall within the bounds of possibility. In the present state of knowledge, at all events, the only thing which can be done for it is to remove the lens from the axis of vision by operation. In former times this was often accomplished by a method called "couching," in which the opaque lens was simply pushed down into the vitreous cavity; but in the present day it is always removed from the eye by extraction. Of late years, the methods of extraction have been much improved, and the percentages of success have increased in a corresponding ratio; for which reason it is unnecessary to go back over the history of the operation, and to trace the steps by which the methods now in use have been arrived at. The history of successive improvements is to be found in the literature of the subject, which is easily accessible to all who desire to be acquainted with it.

The first and most important consideration in dealing with any case which justifies operation at all is, "When should the operation be attempted?" A few years ago the reply would have been, "Not until complete maturity has been attained." Other features of the case must in the present day be taken into consideration.

The advantage of maturity in cataract extraction is simply this, that the cortex, so long as it retains its transparency, retains also a certain amount of viscidity, and adheres with some tenacity to the interior of the capsule. Hence, when the surgeon has pressed out the nucleus, the most superficial layer of the cortex is apt to remain behind on account of its viscidity, while, on account of its transparency, it is so little conspicuous that it may easily escape notice. After being exposed for a few hours to the action of the aqueous humour, it swells and becomes opaque, so that, when the eye is examined, the anterior chamber is occupied by a flocculent mass, which must be either removed or absorbed before vision can be restored. In a young subject the absorption would present little or no difficulty; but old eyes are very intolerant of the presence of swollen cortex, which in them often excites serious and destructive inflammation. Even when matters are not so bad as this, the residual cortex scarcely ever fails to excite some degree of iritis, always a troublesome and formidable complication, which at the very least must retard the recovery of the sight. On the other hand, in many improved methods of operating, even if the remaining cortex were visible, it could not be removed without subjecting the eye to excessive and injurious manipulation, such as might not improbably lead to loss of vitreous, always a source both of present and future danger. When the cataract is fully "mature," the cortex is conspicuous, and is scarcely at all adhesive, so that it readily follows the nucleus out of the eye, and is both easily detected and easily removed if it remains.

If there were nothing but the eye to consider, therefore, the advantages of awaiting complete maturity would be so great as to counterbalance every other consideration. But, as a matter of fact, there is also the patient to whom the eye belongs, and whose position may be in many ways injuriously affected by prolonged blindness or semi-blindness, and by prolonged anxiety. Dividing patients roughly into the poor and the rich, or into those who are dependent upon, or who are independent of, the pursuit of some vocation or industry, it is manifest that the condition of the former may be very seriously affected by the slow progress of senile cataract, especially if it should attain a sufficient degree to produce impairment of vision at a comparatively early period of life. Loss of employment, with corresponding diminution of comfort, and even with curtailment of necessaries, may easily follow from diminution of sight; and such a loss, which might be retrieved if sight could be speedily restored, would soon become irretrievable if the restoration were long delayed. The disabled worker would fall out of the grooves of his occupation, and his place would speedily be filled up by others. Among the classes who are independent of occupation, and in whom, therefore, no physical evils are to be feared, it often happens that the anxiety arising from a consciousness of the slow approach of blindness exercises a very prejudicial effect upon the health, interfering with sleep and disturbing nutrition. Other things being equal, the mere progress of time tends to diminish the chances of good recovery from any surgical operation; so that a patient at seventy is a less favourable subject than one at sixty-five; and when to this unavoidable condition we have to add the injurious physical or moral influences referred to, it is obvious that delay in the extraction of cataract is in itself an evil, and that the surgeon should endeavour to accomplish, at the earliest possible period, that which must eventually be necessary. The delay which tells favourably upon the condition of the lens may tell unfavourably upon the condition of the patient; and the best results will be obtained by the operator who holds the most correct balance between more or less antagonistic conditions. It will perhaps be the most helpful course, in relation to the elements of this problem, to describe first the method of operating for mature cataract, and then the modifications which may be required in order to operate successfully for one that is in an earlier stage of development.

When cataract is mature, and when the eye appears, by the application of the tests already mentioned, to be in other respects healthy, there can generally be no reason for delaying the operation. In this, as in every other important surgical proceeding, care must be taken that the condition of the patient is as good as it can be made, and that no accidental or temporary ailment is permitted to diminish the chances of success. Among such, cough requires to be considered, and, if it be severe, recovery from it should be waited for. It is a good plan to administer a mild but effectual purgative on the day before the operation; but, beyond this, no special preparation will in ordinary cases be required.

There have been many endeavours to extend to ophthalmic operations generally, and especially to cataract extraction, the principles of what is called "antiseptic surgery," but the limits within which this can be done are well defined. The use of carbolic spray, or of carbolic water, is not desirable, and tends to produce irritation of the cornea, or even much disturbance of its surface epithelium. The antiseptic application which I prefer to all others is a twenty per cent. solution, in distilled water, of Professor Barff's boro-glyceride. The instruments to be used, and especially all those which may have to be introduced into the anterior chamber, should be carefully cleansed in very hot water, should be dipped into absolute alcohol immediately before the operation, and then wiped dry with a clean cambric handkerchief.

Some fragments of fine sponge are indispensable, since neither cotton-wool nor any other material will absorb fluid with so light a touch. The same pieces may be used again and again, with the advantage of certainty that they are absolutely free from grit; but especial care should be given to the method of cleansing and preparing them. They should first be well scalded in plenty of boiling water, and then immersed for five minutes in a mixture containing about two drachms of Condy's Fluid to six ounces of distilled water. They are then to be washed and squeezed, and to be placed in a mixture of two parts of distilled water with one of the sulphurous acid of the Pharmacopœia, in which they may remain five or ten minutes, prior to being finally washed in pure water. They will be almost white in colour, and of a peculiar softness due to the destructive action of the Condy's Fluid upon the sponge tissues. After the operation they may be simply scalded in water, and put away until they are required again, when the use of Condy's Fluid and of sulphurous acid should be repeated.

Even if only one eye is to be operated upon, both should be prepared with cocaine, lest the eye under operation should make an undesigned movement in response to some surface irritation of its fellow. For the eye to be operated upon, a single wafer containing the fiftieth of a grain of cocaine hydrochlorate should be placed within the lower lid twenty minutes before the time fixed for commencement. After the lapse of ten minutes, by which time the eye surface will be insensitive to any ordinary contact, the patient should look down, and, the upper lid being gently lifted, two more wafers should be placed side by side upon the upper part of the corneo-scleral junction, and the lid lowered over them in such a way as not to disturb their position. Two more may be applied in the same way in another five minutes, and then one wafer to the eye which is not to be the subject of operation.

Assuming the cocaine to have been applied by the nurse in the manner and at the times directed, the surgeon, on his arrival, will find the eye ready for the commencement of proceedings. He should then wash the conjunctival and corneal surfaces, the lid margins, and the eyelashes, with the boro-glyceride solution, applied with sufficient freedom to remove the gelatine of the wafers, and wiped away when the cleansing is complete. In the meanwhile the sponges, previously prepared as directed, should also be moistened with the solution, and should be squeezed free from all superfluity of it.

The patient should be placed upon his back on a couch, sofa, or table of convenient height, with pillows so arranged as to render the plane of the face horizontal. He should be directed to separate his lips a little, and to breathe gently and rhythmically; and should be cautioned that he may possibly feel some instrumental contact, and that he must not move in consequence of it. He should be practised in looking upwards or downwards, to the right or to the left, at the direction of the surgeon, and should be told when the moment of puncture has arrived.

The position of the couch in reference to light should be carefully considered. In a general way the foot of the couch should be almost in contact with a window, and the length of the couch at right angles to this window; but the position must be such that the hand of the operator will not cast a shadow over the eye. Even on a cloudy day a window which could receive direct sunlight is to be avoided, as inconvenience might be occasioned by the sun bursting suddenly through the obscurity. Other things being equal, a more useful light is obtained from a high window than from a low one.

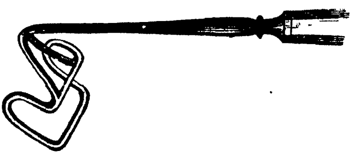

Fig. 35.—Noyes's Elevator.

All things being ready, a surgeon who has no assistant may separate the eyelids by one or other of the forms of spring speculum; but when there is an assistant it is better to commit to him the custody of the upper lid, which should be raised and held by the instrument known as Dr. Noyes's elevator (Fig. 35), a double loop of fine wire upon an ivory handle. I have, I think, improved this instrument by rendering its groove curvilinear, and thus better adapted to the natural curvature of the tarsal cartilage. The assistant should lock the upper lid beneath the orbit, and the elevator should not be permitted to exercise pressure upon the globe. The hand of the assistant, which should be the left for the right eye of the patient, and *vice versâ*, should be passed between the hands of the operator, and should be maintained in one position a little above and behind the forehead of the patient.

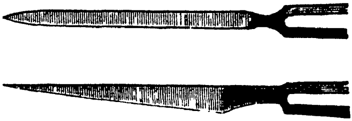

Fig 36.—Cataract Knives.

The surgeon then takes the knife in the right hand for the right eye, and in the left hand for the left, and the fixation forceps in the hand not required for the knife. The latter has a straight back, a sharp point, a narrow, slender blade, and a cutting edge. Two forms are in use—that of Linnhardt, which is commonly called Von Graefe's, and that of Dr. Bell Taylor. In Linnhardt's knife (Fig. 36) the back and edge are parallel, and the point is obtained by an equal sacrifice of both. In Bell Taylor's knife the back is straight to the tip, and the cutting edge meets it at a gentle angle, the point being formed by their meeting. The question is not an important one; but, of the ordinary patterns depicted above, I think that of Dr. Taylor encounters the least resistance from the tissues. For my own use, however, I prefer a knife like that of Linnhardt, but reduced to the smallest dimensions to which a cutting edge can be given.

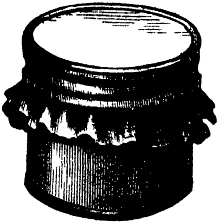

Fig. 37.—Testing Drum.

Before either knife is used, its point and edge should be carefully tested, and should be in perfect

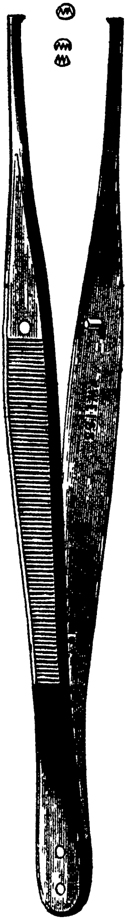

Fig. 38.—Fixation Forceps.

condition. The best means of testing is by a piece of split kid leather stretched upon a metal drum, as in Fig. 37. The point of the knife should penetrate the kid noiselessly, almost by its own weight, and the edge should make a clean section, without encountering appreciable resistance.

The fixation forceps should have four teeth on one blade and three on the other, as in Fig. 38, these being turned at right angles to the blade, so that the forceps, when closed, present a circular flat extremity to the surface of the eyeball.

The surgeon directs the patient to look up, and with a finger of the knife-hand draws the lower lid a little downwards. With the forceps he pinches up a vertical fold of conjunctiva a short distance below the cornea, on the vertical meridian, getting hold of a little of the subconjunctival tissue, and so placing the forceps that they point to the centre of the eyeball. In this position they prevent the lower lid from rising to be in the way. The patient is then directed to look a little downwards, the forceps being moved in a corresponding degree, and the surgeon enters his knife behind the corneal margin, but in front of the iris, and at a point about one millimetre below a tangent to the upper margin of the cornea. (*See* A, Fig. 39.) The knife should be held like a pen, its cutting edge uppermost, and the plane of its blade parallel to that of the iris. It is to be carried downwards through the anterior chamber, in front of the iris, nearly to the spot marked B in the figure, then raised by depressing the handle, and carried horizontally across the chamber to a point C opposite that of entrance, where it is made to emerge by a counter-puncture, which, when the point of the knife reaches the selected spot, should be made by a quick thrust. The blade is then pushed on, its cutting edge pressing against the bridge of intervening tissue, and directed somewhat forwards, so as to bring the middle of the resulting incision to a point a little anterior to those of entrance and exit, and barely within the tissue of the cornea itself. If the point of the knife should reach the side of the nose before the section is completed, it must be gently drawn back, with no attempt to make it cut as it recedes, and then once more brought up and pushed forward. The last portion of the bridge of tissue should be divided very slowly and gently, and, as the knife passes through it, the surgeon may relax his hold on the forceps, and the assistant may release the upper lid. It is hardly necessary to observe that the precise length of the incision, as determined by the points of puncture and counter-puncture, should be modified in accordance with the surgeon's estimate of the diameter of the hard nucleus.

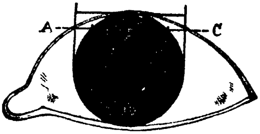

Fig. 39.

The very narrow knife which I now use affords great facilities for inclining its edge forward, and thus giving any desired profile curvature to the section, without the possibility of injurious pressure being exercised by its back upon the iris or lens; but it is more liable than a broader blade to permit a premature escape of the aqueous humour, with consequent prolapse of iris upon the cutting edge. In order to obviate this, it is necessary to oil the blade, as advised for needles on page 216, to carry it across the chamber as quickly as possible, and, until the counter-puncture is completed, to press the back of the blade against the puncture, so that this may not be enlarged by the cutting edge.

Perhaps the most difficult part of the above described procedure consists in the preservation of the right relations between the operating and the fixing hand. The surgeon must acquire the knack of attending equally to each of them, and of making them work together in perfect harmony. Not only must the forceps exert no pressure upon the globe, but it must do no more than just steady it against the knife, so as to counteract any tendency to rotation towards the nose.

After a moment's rest, the surgeon gently lifts the upper lid, and frees the eye from aqueous humour, or from blood issuing from divided conjunctival vessels, by the gentlest possible touch with the point of one of the fragments of sponge. The next step is to excise a piece of the iris; and, before this is attempted, the patient should be warned that he may possibly feel some pain.

The suggestion that iridectomy should be an essential part of cataract extraction was first made by Von Graefe, although it was first carried into practice by Mooren; and as, of late years, some surgeons have dispensed with this part of the operation, it is worth while to state the advantages of retaining it. The operation for cataract which is now known as flap extraction, and which held its ground for a century, was performed by severing one half of the cornea from its scleral margin, and by pressing out the lens through the natural pupil and the large external wound. The risks attendant upon this procedure were mainly two; the first being that the bruising of the iris by the forcible dilatation of the pupil was liable to excite acute inflammation; the second, that the extensive severance of the cornea from its sources of nutrition was liable to produce necrosis. Either of these events —either acute iritis immediately after the operation, or necrosis of the cornea—was always followed by suppuration of the eyeball and loss of sight; and these consequences occurred in a considerable percentage of cases. The iridectomy, by enlarging the pupil, and by removing the portion of iris which was most exposed to bruising—that is, the portion between the margin of the pupil and the external wound—at once greatly diminished the liability to iritis; and it was soon found that the increased facility for the exit of the lens, which was afforded by the enlarged pupil, would allow this exit to take place through a smaller external opening, and would by so much diminish the liability to sloughing of the cornea. A third complication which not unfrequently caused trouble, and which is entirely obviated by the iridectomy, was prolapse of the iris through the wound, which from its size and shape readily reopened, after the most careful co-aptation of its edges. When a case in which iridectomy has not been performed turns out well, nothing can be more excellent than the visual result; but the value of the iridectomy depends upon the fact that it largely increases the percentage of success. It is especially valuable in all cases in which a state of impaired nutrition renders the patient unusually liable to necrotic or inflammatory action; but, even without considering these cases, its beneficial effect upon general averages is sufficiently declared to cast grave doubt upon the prudence of those surgeons who, on the strength of individual cases in which it has not been performed, would argue that it may as a rule be dispensed with. My own experience as an operator not only covers the pre-iridectomy period, but I believe I was the first surgeon who, in 1862, performed iridectomy as part of cataract extraction in England;

and I can entertain no doubt of the general advantages of the practice, or of the desirableness of its being adhered to as a matter of ordinary routine.

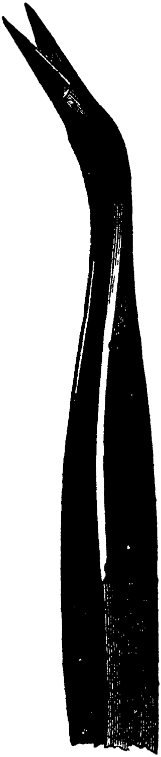

Fig. 40.—Iris Scissors.

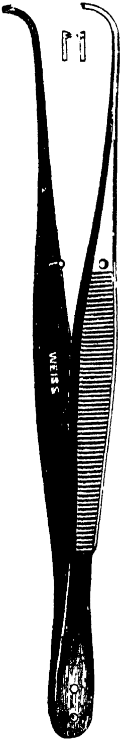

Fig. 41.—Iris Forceps.

In order to excise the iris the re-insertion of the lid elevator is sometimes necessary, but will seldom be required for a tranquil and intelligent patient, whose eyes open fairly wide. With such it is usually enough to direct the patient to look a little downwards, a proceeding which should bring the line of incision well into view beneath the edge of the upper lid. If there be a conjunctival flap, the surgeon turns it over upon the cornea with the iris forceps (Fig. 41), and then introduces this instrument with blades closed in a vertical direction into the anterior chamber, and carries it nearly to the edge of the pupil. Its blades are then suffered slightly to expand, so that a vertical fold of iris rises between them, which is then seized, drawn out of the eye, and excised by any of the ordinary patterns of iris scissors. I was formerly accustomed to perform this excision as in iridectomy for glaucoma, but am indebted to Dr. Reid, of Glasgow, for the knowledge that it may be better done by placing the open scissors upon the cornea, in the vertical meridian with their points upwards, and by simply closing them behind the forceps as soon as the fold of iris has been drawn out to a sufficient extent.

While the iris is grasped by the forceps, a sudden movement of the eye may occasion the detachment of more of the membrane than the piece sought to be excised; and hence, unless the surgeon has full confidence in the steadiness of the patient, it is better to request an assistant to pinch up a fold of conjunctiva with the ordinary fixation forceps, and to hold the eye immovable. By the time this stage is reached, there will be no difficulty in determining whether or not the quiescence of the patient can be relied upon.

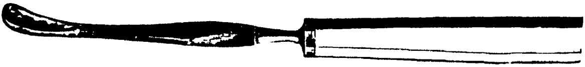

Fig. 42.—Shell Spoon.

The excision of the iris will be attended by slight hæmorrhage, and the effused blood may spread as a film beneath the cornea, and obscure the lens and the rest of the iris from view. The surgeon may apply the fixation forceps in their original position, making slight pressure, by which he will press forward the lens against the cornea, will probably press out the blood, and will support the lens for the next step, the division of the capsule. If the blood does not escape easily, the lips of the wound may be parted by a slender silver scoop, and a moderate pressure may be exerted by stroking the surface of the cornea from below upwards with the shell spoon (Fig. 42), afterwards to be used to complete the extraction. As soon as the pupil is clear, the operator takes the cystitome (Fig. 43), and carries it into the eye with its blunt part forwards, keeping it well up against the inner side of the cornea, until he reaches the lower margin of the pupil. He then carries the instrument beneath the iris for a short distance, turns its point towards the capsule, and divides the latter by a drawing cut right up to the wound. Before the cystitome is withdrawn, another cut should generally be made along the equator of the lens, and from one extremity of the wound to the other.

In most cases it will be convenient to use Von Graefe's fleam-shaped cystitome (Fig. 43), which consists of a tiny triangular blade placed at one side and near the extremity of a slender shaft of steel. When the eyebrows are very large, or when the orbit is very prominent, it will be better to use a slightly curved steel point, carried upon a platinum stem, which may be bent to any required angle. The shoulder of the cystitome and the teeth of the iris forceps are the most likely lurking places for some decomposing residua of a former operation, and hence the cleansing of these two instruments and the final dip into absolute alcohol should be attended to with especial care.

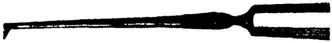

Fig. 43.—Graefe's Cystitome.

The capsule being divided, a portion of cortical matter will often escape from the eye, and the bulk of the lens will advance, distending the enlarged pupil. Directing the patient to look down, the surgeon gently separates the lids with his fingers, and makes gentle pressure upon the lower part of the cornea with the back of the shell spoon already mentioned. The first position of the spoon should correspond with the lower margin of the lens, and the first pressure should be directly backwards, so as to cause the lens to rotate on a horizontal axis, and to present its upper margin at the wound. The pressure may then be transformed into a movement of stroking upwards, the spoon being kept below the largest bulk of the lens, and being made to urge it forward, and to help it gently through the aperture. As soon as the diameter of the lens has passed through, the pressure should he stopped, and the rest suffered to glide out without farther interference.

If, when pressure is first applied, the lens makes no show of advancing, the capsule may be insufficiently divided, and the cystitome should be re-introduced. If the progress outwards is arrested before the greater bulk has passed through, the incision is probably too small, and the surgeon must consider whether this is so, and, if so, to what degree. By dexterous management of pressure, and by holding back the posterior edge of the wound with the tip of a flat scoop, a lens will pass through an opening which ought to have been larger; but if the discrepancy between the two magnitudes is considerable, the safest plan is to enlarge the section at one extremity by knife or scissors.

The proper management of pressure is the last attainment of the operator for cataract. By skilful and practised hands, pressure (either through the medium of the spoon or directly with the finger-tips) may be exerted in a way which, if attempted by a novice, would infallibly occasion the expulsion of vitreous humour; and the practical lesson of this is that the young operator should always make his external wound a trifle large, rather than too small. The easier the door of exit, the smaller is the degree of pressure which will be required.

When the great bulk of the lens has passed out of the eye, no vitreous following it, the chief object of the operation may be said to have been attained, and the patient may so be told; but the steps which remain are fully as important as those which have been accomplished. The surgeon should endeavour to clear the anterior chamber of every fragment of cortex, leaving nothing which can excite irritation, and thus affording every prospect of immediate union.

The lid being once more raised, it will generally be seen that fragments of cortex are lying about the wound, and that perhaps a few shreds of coagula project through it. The cortex may be wiped away by the tip of a morsel of sponge; the coagula may be picked up and withdrawn by forceps. When this is done, if the pupil is of a clear bright black, the surgeon may test the vision by holding his open hand in such a position that it may be seen by the patient. If it is clearly distinguished, the patient may next be asked how many fingers are held up, and may be called upon to name a thumb or a little finger, and to say whether there is a ring upon the latter. If he can do all these things, there is little or no residual cortex, and the operation is complete. If the answers are uncertain, the surgeon should make gentle rotatory friction upon the eye through the closed upper lid, in order to bring towards the centre any cortex which may be lurking behind the marginal parts of the iris; and then, by a renewal of the upward stroking pressure upon the cornea with a spoon, or with the finger covered by the lower lid, he may coax any such residue through the wound. Quite a large quantity will sometimes be obtained in this way; and the direction of the pressure must be guided by knowledge of the anatomy of the parts. The emergence of the lens will have left vacant a sort of cavity in the front of the vitreous body, and the cornea may sometimes be pressed well into this cavity before the latter can be completely emptied. Sometimes a slender silver scoop may be gently introduced, and the cortex brought away in its groove; but in one way or the other, whenever possible, the cortex should be entirely removed, and correct answers to the vision test should be obtained.

As soon as this has been done, the last shreds of coagula should be picked away from the conjunctival sac and from the edges of the wound, the conjunctival flap should be placed in correct position by a fine shell spatula (Fig. 44), and the patient should be directed quietly to close both eyes and to open them no more. The final dressing should then be applied; and after many trials of different methods I prefer the following to all others:

Fig. 44.—Shell Spatula.

A piece of old pocket-handkerchief about an inch and a half square, with its edges cut free from loose threads, should be well smeared with "sanitas vaseline," laid over the closed lids of each eye, and moulded to them by light pressure, so as to lie upon their curvatures without a wrinkle. The vaseline will absolutely prevent the dressing from becoming hard, or from sticking to the skin of the lids. A small ball of cotton-wool, preferably not of the kind which is called "absorbent," should then be soaked in lukewarm water, freed from any superfluity of moisture, and moulded by the fingers so as to be concave on one side and convex on the other. The concavity should be turned towards the eye, and should be of a size to fit the surface of the upper lid, while the convexity should be outwards; and the ball of wool as a whole should be just large enough to correspond with the opening of the orbital cavity and to give a light but firm holding to a horizontal bandage. This bandage should be a strip of knitted cotton about three inches in width, and long enough to reach over the wool pads to points just behind each ear of the patient. I formerly used the narrow bandage shown in the figure; and have once more to acknowledge my indebtedness to Dr. Reid for showing me the broader one, which obtains a firm hold upon the forehead without exerting pressure upon the eye. The band should have three pairs of tape strings: one pair to be tied horizontally; two other pairs at right angles with the former, one to be tied over the vertex, the other beneath the chin. (*See* Fig. 45.) The pads should be applied to both eyes, even when only one has been operated upon, and the strings should be tied pretty firmly, as support will generally be pleasant to the patient. An attempt has been made to dispense with the pad and bandage, and simply to close the lids by a morsel of plaister. This method, which is now brought forward as a novelty, was the practice invariably followed until about five-and-twenty years ago, when the pressure bandage was advocated by Von Graefe as part of the new plan of operating which he introduced. It might have been thought that the advantages, to a healing wound, of complete

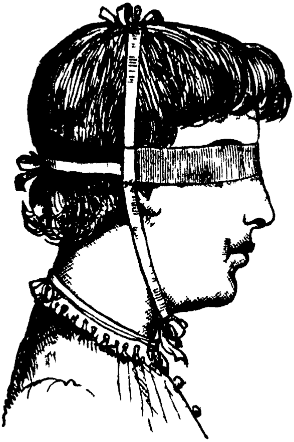

Fig 45.

shelter, and of gentle uniform support, would have been self-evident; but it appears that there are still surgeons who require that these advantages should be made the subjects of demonstration.

When the bandage described above is not at hand, a small roller may be used as a substitute for it. This should be about an inch and a half wide and nearly two yards long, and is best made of either "water-dressing bandage" or of flannel gauze. The free end of the roller should be placed on the forehead over the affected eye, and the first turn should be made across the forehead and round the head horizontally, so as to secure the end. When the roller reaches the forehead, over the sound eye, for the second time, it should be inclined downwards, carried just over the ear, round the occiput, under the lobe of the second ear, and then upwards across the face, over the affected eye, to the forehead. Before the roller is brought over the affected eye, the pad of wool must be placed in position; and the pressure exercised by the bandage must be carefully regulated. When the roller reaches the forehead, it should be secured to the horizontal turn by a pin, and then a second horizontal turn over all will complete the application, unless it is desired to bandage both eyes, in which case the roller may be brought down from the forehead over the second eye, carried round under the lobe of that ear to the occiput, and back to fasten to the horizontal portion as before. This bandage is very little liable to slip, but some heads are more favourably shaped for its application than others, and it is generally desirable, at night, that its several turns should be secured to one another by the insertion of a few stitches of cotton.

With cocaine, the best time for operating is usually about 2 p.m., which allows the patient to have luncheon and a glass of wine an hour previously, and the first visit should be paid in about six hours. If the eyes are fairly comfortable, the bandage should be left alone, and nothing need be done beyond prescribing a sedative to be taken if there should be pain or restlessness. The knowledge that something of this kind is accessible will often supersede the necessity for taking it. If the eyes are uncomfortable, the bandage should be untied and the pads removed and replaced, a proceeding which, thanks to the vaseline, will be easily accomplished, and will often restore comfort. If there be actual pain, it will generally be prudent to administer a little morphia hypodermically.

As bearing upon the question of pain, it must be remembered that cataract extraction seems usually to be followed by a rather free secretion of aqueous humour, which distends the anterior chamber and presses upon the wound. This pressure often occasions what a patient will declare to be severe pain, but which is soon relieved by the escape of the superabundant fluid through the lips of the wound. The patient should be prepared for this occurrence, lest it should occasion alarm, and should understand that neither he nor the surgeon need be troubled about an occasional twinge which a gush of fluid relieves.

The dressing should be renewed on the following morning, and the lids cleansed with a morsel of moist wool or sponge. The lids should not be opened, and the surgeon may be confident that all is well if they are of natural appearance. Any redness or general swelling of the lids would at this period be a very bad symptom; but slight œdema of the upper lid near its internal angle is common, and may be disregarded. The dressing may be changed evening and morning, and when forty-eight hours have elapsed since the operation, the patient should be directed to look down, while the upper lid is so far lifted as to afford a glimpse of the cornea. If, as usually happens, this is clear and bright, and the wound is so far united that the anterior chamber is restored, the patient may be assured that his sight is secure. Complications are still possible of a kind which may delay recovery, but there is hardly anything which can entirely vitiate the result. After forty-eight hours the cornea does not slough, nor does iritis develop into general inflammation and suppuration of the eyeball.

It has already been advised that when the eye to be operated upon is of undue tension, the iridectomy should be made a preliminary proceeding; and the same course should be pursued in most cases of high myopia in which the patient is of broken health or very advanced age, and whenever there is manifest arterial fragility. There will be less liability to internal bleeding, in any of the foregoing conditions, if the intra-ocular tension is thus gradually reduced, than there would be if the iridectomy and the extraction were performed together, so that the internal vessels were suddenly deprived of support.

It is next necessary to consider how the course of proceedings should be modified when it is desired to extract a cataract which is not fully mature, but in which the cortex is still partially transparent, and still adherent with some tenacity to the interior of the capsule.

The question will not arise, of course, as long as the patient has sufficient vision to read print of even moderate size, or to follow any occupation for which critically minute vision is not required. In other words, it cannot arise until opacity has made considerable progress, even though in this progress much time may have been occupied, and the prospect of complete blindness may still be comparatively remote. In these conditions the best results will be obtained when there is what has been described as a "hard" senile cataract; that is to say, when the nucleus is large and the cortex comparatively small in quantity. By focal illumination the distance of the hard, nuclear, or amber-tinted portion of the lens from the surface may generally be determined with tolerable accuracy.

When an attempt is decided upon to extract a cataract which is not fully "mature," the patient must be prepared for some slight increase of the ordinary risks of failure, and must be willing to incur this increased risk for the sake of some manifest advantage.

The operation should invariably be divided into two parts, the iridectomy being made a preliminary step, separated from the extraction by not less than six weeks. By adopting this course, the cut edges of the iris will be soundly healed before the lens passes through them; and it is found by experience that any residual cortex left in the eye is much less liable to excite iritis when in contact with healed edges than when in contact with the edges of a recent wound. The iridectomy should generally be of larger size than is either necessary or desirable when the lens is mature.

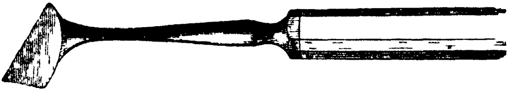

Fig 46 —Iridectomy Knife.

For the performance of a preliminary iridectomy, the general arrangements, *i.e.* the application of cocaine, the position of the lid elevator and the fixation forceps, should be the same as for extraction, but a different knife is used for the incision. We employ a triangular blade (Fig. 46), set at an angle upon its stem, and cutting on both edges. This is slowly thrust into the anterior chamber, being made to enter barely in front of the iris, and being carried on with a steady push, its point being guided over the opposite margin of the pupil, until the length of the incision corresponds with the width of iris which it is intended to remove. The iris is drawn out and excised in the ordinary way, and both eyes are closed, as after a cataract operation. After the third day a weak solution of atropine should be instilled, in order to prevent the adhesion of any part of the cut edges of the iris to the capsule of the lens.

It is sometimes found that the performance of iridectomy, by virtue of the alteration which it produces in the tension of the eye and in the circulation of its internal fluids, hastens maturation; and within six weeks after the first operation I have more than once seen a cataract ready for extraction, by whatever test it was tried. Assuming that no marked change has occurred, the second stage is to make an incision as already directed for extraction, and immediately, no further iridectomy being required, to divide the capsule freely, and to press out the lens through the wound. As already stated, the most favourable cases will be those in which the cortex is small in quantity, the nucleus correspondingly large; and on this account it is important to make the external wound sufficiently large to provide for the easy exit of such a nucleus as may be expected. The largest ordinary diameter is from seven to eight millimetres, and the length of the internal wound should be perhaps half a millimetre more. The external wound, from the formation and physical conditions of the eye, must be at least one millimetre longer than the internal is required to be. The use of cocaine affords both to surgeon and patient the enormous advantage of plenty of time; there being no need to close and bandage the eye hastily for fear of sickness or of muscular spasm, and hence, when the cortex is not fully ripe, the lids may be closed, and the operator may wait ten minutes. Even in this short period a thin layer of cortex will undergo a definite amount of softening, and the greater portion will be brought out of the eye by the manipulations already described, which will probably require to be continued (with extreme care, of course, but with some little perseverance) before satisfactory answers to the questions about vision will be obtained. In some cases it will be necessary to close the eye, although some cortex is still contained in it, and to trust to atropine and general treatment for the prevention or control of iritis whilst this residue is being absorbed.

Dr. McKeown, of Belfast, has lately suggested the feasibility of washing out the lens capsule in such cases by a stream of distilled water, which, he says, will bring away the whole of the immature cortex rapidly and completely. He has designed a syringe for the purpose, and recommends that the water should be raised to the boiling point at the time of operation, and suffered to cool down to about 100 degrees before it is used. I have employed this method in a few instances, but have not been sufficiently impressed by its advantages to be able to recommend it for general adoption. Neither can I speak more favourably of a process which has been called "artificial maturation," and which has been recommended and practised by some surgeons. In this procedure, the anterior capsule of the lens is divided by a cataract needle, either without or subsequently to an iridectomy, in order to expose the superficial cortex to the action of the aqueous humour, and thus both to render it conspicuous and to prepare it to leave the eye with facility. Excellent results have, there can be no doubt, been obtained in this way; but the liberation of the cortex thus produced, and the increase in bulk which it undergoes, are very liable to set up dangerous internal inflammation, which may not subside after extraction, and which may lead on to complete wasting of the eyeball.

As a practical matter, the decision whether to risk an operation upon a comparatively immature cataract should be greatly determined by the general condition of the patient. This was long ago discovered by Von Graefe, who, in cases in which the cataract in one eye was mature, and in the other immature, advised that if the recovery from the extraction of the mature cataract was speedy and complete, the surgeon should "proceed boldly," and should extract the second and immature cataract shortly after the former.

The question whether to operate on one eye or on both has given rise to much discussion, and may, I think, be generally decided upon the following lines:

If both cataracts are mature, and the patient is very aged or feeble, operate on both eyes at the same sitting. Out of the two, one is almost certain to do well; whereas if one alone is done and proves a failure, the patient will be unlikely to submit to a second operation.

If both cataracts are mature, and the patient is of good strength and intelligence, the operator should claim to exercise his own discretion in the matter. If the first operation is entirely satisfactory, proceed at once to the second; but if any complication occurs in the first (loss of vitreous, retention of cortex, or the like), wait for the recovery of the first eye before proceeding to the second. The progress of the one may throw much light upon the management of the other.

If one cataract is mature and the other immature, operate upon that which is mature as soon as it is ready, even if that of the second eye be in a very early stage. Success will at once relieve the patient from all fear of future blindness, and the eye operated upon will have the advantage of a long rest before it is called upon to replace its fellow.

If both cataracts are immature, and for any reason it is desirable to endeavour to afford the patient the earliest possible relief, operate only on the eye which is the least useful. If it does well, act upon Von Graefe's maxim, and proceed boldly with the other; but if it does badly, especially if the failure arises from any cause likely also to be operative with the other, do not touch this until maturity is complete, and until the patient is so blind that he has all to gain and nothing to lose.

It remains to consider the accidents and misfortunes by which a cataract operation may be complicated, and the management of cases in which healing is protracted or disturbed.

The most frequent complication which arises during the operation is loss of more or less of the vitreous body, which in aged people is often of unnaturally soft consistence, and is therefore specially liable to escape. This accident is frequently caused by spasm of the external ocular muscles, or by the strain of vomiting, and hence it is much less likely to occur under cocaine than when a general anæsthetic is employed. A patient might be quite insensitive to pain, and general anæsthesia might be carried quite as far as prudence would allow, without its being sufficiently profound to prevent reflex spasm of the recti. If these muscles inflicted a sudden squeeze upon the eyeball, rupture of the hyaloid membrane and loss of vitreous were very likely to ensue.

In completing the extraction of cortex, the surgeon will sometimes see the hyaloid, with its contained vitreous, projecting between the lips of the wound, so that a very small additional force would produce rupture. He should immediately desist from his endeavours, suffer the upper lid to fall, and support the eye by gentle pressure with a pad of cotton wool. After a few moments the lid may be again raised, and it will probably be found that the hyaloid has returned to its natural position. If the state of vision suggests that cortex is still retained, it will be better to avoid any farther pressure, and to remove as much as possible by the dexterous employment of a small scoop, carried between the lips of the wound.

In other cases there will be no warning, and the vitreous will escape suddenly. If the amount lost be only small, and if the patient be quiet and well-behaved, an attempt may still be made, after a short rest, to remove any visible and accessible fragments of cortex with the scoop, but these attempts must be at once abandoned if further loss of vitreous should occur. When the first escape was considerable in quantity, the eye should be closed at once.

The dangers attending a loss of vitreous are in almost precise proportion to its quantity, and are greater when it is fluid, and thus affords evidence of general failure of nutrition in the eye. A small loss may make no apparent difference in the results of the operation; a large loss is frequently followed by chronic inflammation and ultimate wasting of the eyeball.

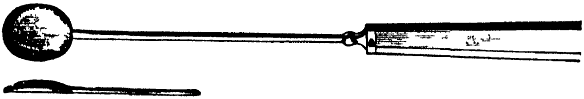

Fig. 47.—Pagenstecher's Spoon

Prior to the extraction of the nucleus, vitreous may escape at any step of the operation, *i.e.* immediately upon the completion of the section, during the performance of the iridectomy, or during laceration of the capsule, or as soon as pressure is applied to promote the exit of the lens. The earlier it occurs, the more certainly does it point to the existence of degenerative change.

If vitreous escapes prior to the performance of the iridectomy, that step of the operation should be completed with the least possible delay, and no attempt should be made to divide the capsule, since the cystitome would almost certainly push the lens before it into the deeper parts of the eye. The surgeon should take a flat spoon or a metal loop (Pagenstecher's spoon or Taylor's vectis, Figs. 47 and 48), and should pass it quickly and boldly behind the lens, raise the latter against the cornea and extract it, and at once close the eye. The same course should be pursued if vitreous escapes after division of the capsule, or upon the application of the usual pressure, to continue which would only expel more vitreous, while the lens would recede to occupy the position of that which had escaped. In operating upon an eye which is the subject of Morgagnian cataract (page 205), the fluid cortex will escape as soon as the capsule is divided. The nucleus, however, from its small size and hardness, frequently eludes the action of external pressure, by which, at the same time, the safety of the vitreous is imperilled. In such cases it is prudent to use the scoop or vectis, if the nucleus does not at once present itself; or some operators prefer a small sharp hook, which they stick into the nucleus and use as an instrument of traction.

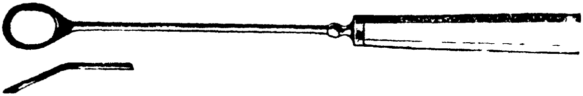

Fig. 48.—Taylor's Vectis.

Besides loss of vitreous the only accident liable to occur during or immediately after the operation is rupture of a blood-vessel in the choroid, and consequent hæmorrhage. Under present methods of operating, this occurrence is very uncommon, although it was comparatively frequent when extraction was performed, as was the case until about twenty years ago, through a large corneal section. Considering the average age of cataract patients, and the liability of old people to degeneration of blood-vessels, it is almost surprising that intra-ocular bleeding is not more frequent. When it occurs, it is generally discovered before the eye is closed, the deep hæmorrhage pushing before it the vitreous, which soon protrudes at the section, and is followed by blood. After such an occurrence, there is no possibility of vision, and the patient is likely to suffer much pain and distress before the eye dwindles and becomes quiescent. The best course is to administer ether or chloroform, and to proceed to enucleation or evisceration as soon as the accident is discovered.

In following the old method of extraction, the so-called "flap operation," something like fifteen per cent. of all the eyes operated upon were lost by suppurative inflammation, which usually commenced on the second day, sometimes as iritis, sometimes as necrosis of the cornea, and was attended by much swelling of the lids, with discharge at first serous and afterwards purulent. Such an issue is now extremely rare; and is only likely to happen in cases which from their nature, or from the debility of the patient, would from the first be so hopeless that the efforts of the surgeon would be limited to the relief of pain. Enucleation of the eye is hazardous when general inflammation exists, and the best course in such cases is to administer an anæsthetic and to divide the sclera freely in two or three directions, so as to relieve tension and to permit the easy escape of the contents.

Even in the most favourable cases, and especially when any portion of cortex has been left behind, extraction is liable to be followed by slight iritis, sometimes so slight that its existence is scarcely recognised, but which leaves the pupil occupied by delicate films which interfere with vision, and to which the margin of the pupil is at one or two points adherent. If the iritis be mild, it will require no other treatment than the daily instillation of a solution of atropine, which may be commenced about the third day or afterwards, with careful protection of the eye; but if it be severe, and the patient's condition will allow, a leech may be applied to the temple. If cortex has been left behind, so as to be a probable source of irritation, it may sometimes be evacuated by a puncture with a broad needle, through which, being by that time softened, it will usually escape readily; and after this the eye will frequently quiet down. In other cases, even in those in which the inflammation is not of great severity, it may prove intractable, and may lead on to involvement of the ciliary processes and choroid, and to ultimate wasting of the eye, which is sometimes left tender and troublesome, and may require to be removed as a possible source of danger to its fellow. In some of these obstinate cases, the inflammation is probably of septic origin; and the resources of treatment are almost limited to rest, shelter, the support of strength, the relief of pain by anodynes, the application of atropine, and of an occasional leech to the temple in congestive stages. To the fulfilment of two of these indications, the administration of quinine, combined with small doses of morphia, will often be highly contributory. When iritis has entirely subsided, and congestion has disappeared, if focal illumination displays any pupillary films which interfere with the desired visual result, they must be torn through by two needles used in the manner already described. (*See* page 209.) I have heard of cases in which this apparently trivial final proceeding, in old people, has been followed by severe and even destructive inflammation, an effect which may perhaps have been brought about by the premature performance of the operation, and perhaps by the use of imperfectly cleaned needles. The shoulder of the point of the needle is a possible lurking-place for the residua of former operations, and the cleansing of the needles in absolute alcohol should never be omitted. After the laceration of films, wool compresses moistened with water should be applied, and renewed from time to time for twenty-four hours.

In some cases in which films have formed in the pupil, and have become adherent to its lower margin, they may by their contraction drag upon this margin and draw it upwards, until the lower part of the iris may reach, or even ascend above, the centre of the cornea; and a similar dragging upwards is sometimes produced, without any film formation, by contraction about the ends of the external wound, in which portions of iris may become entangled. In either case the displacement of the pupil is detrimental to vision; and, even when this displacement is caused by the contraction of films, the iris seldom resumes its natural position when they are simply torn by needles. In such cases it is desirable to divide not only the films, but also the iris itself to such an extent as to leave an opening behind the centre of the cornea; and this may be done with the scissors figured and described on page 210. The cut is usually most effectual if made downwards in the vertical meridian. When the scissors are withdrawn, the contraction of the fibres of the iris should widen the gap, and convert the cut into a V-shaped opening.

There is yet one more method of cataract extraction which requires mention, and which has many advantages in the comparatively small number of cases in which it is practicable. In some old people the tenacity of the capsule of the lens is greater than the strength of its attachment to the hyaloid membrane, so that the lens may be pressed out of the eye in its unbroken capsule, bringing away, of course, the whole of the cortex therein, and leaving no possible source of irritation behind, in fact nothing but a simple incision, which is likely to heal by the first intention. Such a condition is only found, according to my experience, when the cataract is mature; and in such cases extraction in the capsule should be attempted. The original incision should be sufficiently large to permit the easy exit of the entire lens, and the iridectomy should be larger than would otherwise be required. When the iridectomy is completed, the surgeon may apply gentle pressure, and if the lens advances, the extraction may be completed, often with a little assistance from a flat spoon, which may be used to hold back the posterior lip of the wound. If the lens refuses to advance, the capsule must be divided, and the extraction finished in the ordinary way.

It is exceedingly desirable that an eye from which cataract has been extracted should not be taken into use for a considerable time, premature use being a frequent cause of subsequent trouble. The place of the absent crystalline lens must be supplied by a glass lens of appropriate power; and it will be found as a rule that a lens of about ten dioptres will be required for distance, and one of fourteen or fifteen dioptres for reading. If the patient were originally myopic, weaker lenses will suffice; if he were hypermetropic, stronger ones will be required. If, the pupil being quite free from opacities, the visual results are imperfect, astigmatism must be suspected and looked for, and, if found, must be corrected by the addition of the necessary cylindrical elements to the lenses; all this adaptation of glasses being conducted in the way which will be found described in the chapter on refraction. It must be remembered, however, that the curvature of the cornea will be gradually modified, for some weeks or even months after the operation, by the occurrence of slow contraction in the cicatrix; and, until this process has come to an end, the glasses of the greatest permanent utility cannot be supplied.

There remain two forms of partial cataract called from the parts of the lens they affect, anterior and posterior polar.

Anterior polar cataract, which also goes by the name of pyramidal, forms a minute round white spot, which usually projects somewhat from the anterior pole of the lens, and is of course visible by focal illumination. It is usually caused by a perforating ulcer occurring in the course of purulent ophthalmia, as described on page 119, in which case it is always associated with a corneal opacity, which may, however, be very faint. Occasionally this form of cataract is seen as a congenital condition, and without any corneal affection. In this case, if of very small size, it may not interfere at all with vision, and will require no treatment; in other instances an optical iridectomy, such as is described on page 137, is indicated.

Posterior polar cataract usually appears as a central speck with a few short striæ radiating from it. Owing to its position it appears to remain stationary when the eye is moved.

It occurs as a congenital condition, and is then not improbably in some way connected with the hyaloid artery; when it is developed later it usually is secondary to some morbid process in the vitreous or choroid. In any case nothing can be done in the way of treatment. R. B. C.

CHAPTER VII.

AFFECTIONS OF THE VITREOUS.

THE vitreous humour is the clear substance of jelly-like consistence which accurately fills the whole cavity of the globe behind the lens. It is inclosed in a fine, apparently structureless membrane, which has been variously described as identical with, and distinct from, the internal limiting membrane of the retina. This membrane, which has been called the hyaloid, is continuous with the posterior layer of the lens capsule, and forms the posterior boundary of the circumlental space or canal of Petit. There are many points in connection with the anatomy of the vitreous which are still in dispute; it certainly contains in the normal state numerous cells of various shapes, and fine floating filaments, which are probably remnants of older disintegrated cells. These cells are much more numerous towards the peripheral parts. The behaviour of the vitreous under certain re-agents has given rise to an idea that it was traversed and subdivided by numerous septa of a membranous nature. It is, however, extremely doubtful how far such appearances are really normal, and how far they have been produced artificially.

The vitreous receives its nutriment from the ciliary processes, which, there can be no doubt, are the source of most of the cells that it contains. Fluid escapes from the vitreous chiefly through the circumlental space into the aqueous chamber, whence it is absorbed by the canal of Schlemm and the adjacent vessels in the area of Fontana. Recent experiments* have shown that there is also a current from the vitreous through the optic nerve, which follows the central blood-vessels; this is probably connected with the canal of Stilling, and concerns chiefly the posterior part of the vitreous.

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* Gifford, *Arch. of Ophthal.*, June, 1886.

The vitreous humour being devoid of vessels and nerves, while it is in close relation with very vascular structures, is rarely, if ever, the starting point of morbid conditions, while it is frequently affected secondarily to other tissues. Any departures from its normal condition, however, are of importance, since its perfect transparency and normal consistence and quantity are essential for vision. A diminution in its consistency considerably increases the chances of failure in an operation for cataract. A slight increase in its amount may lead to permanent increase of the intra-ocular tension, and produce the train of symptoms included under the name glaucoma; while a diminution in its amount may cause the globe to lose its spherical shape, and the retina its normal position and curvature, or may lead to detachment of the retina. Moreover, the lowered tension thus produced is often the first indication that an inflammatory process has caused permanent changes in the tissues of the eye which will impair its nutrition and probably lead to its ultimate loss.

In the fœtus the vitreous is traversed by the hyaloid artery and vein, which pass forwards from the point of entry of the central retinal vessels to the posterior surface of the lens, where they break up to form a fine plexus. Before birth this, as well as the vessels, should have disappeared; occasionally, however, the whole or part of the vessels persists throughout life, sometimes carrying blood, but much more frequently as a fine fibrous thread. Numerous other vessels have sometimes been seen springing into the vitreous from the optic disc, and have been considered as congenital; it is, however, not improbable that these were really the result of inflammatory conditions. The hyaloid vessels lie in a canal with transparent walls (the canal of Stilling or Cloquet), and this persists throughout life, although it is invisible. It is probably in connection with the lymphatic system, and plays an important part in the nutrition of the vitreous.

Muscæ volitantes.—The shadows which the cells and filaments in the vitreous throw upon the retina sometimes give rise to the subjective sensations of minute objects floating before the eyes—muscæ volitantes. These can be perceived by any one when a pencil of strongly divergent rays enters the eye, as in looking at a uniform bright surface through a pin-hole aperture, or when light is reflected from a very convex surface held close to the eye. They also become visible when from any cause the retina is hypersensitive, or the consciousness unusually alive to subjective sensations. Muscæ, having once been noticed, are apt to prove very annoying, and not unfrequently cause the subject of them considerable alarm. They never impair vision, and from this fact and their invisibility with the ophthalmoscope they can be distinguished from pathological opacities.

"Hyalitis."—When the cells in the vitreous are sufficiently increased in number to impair its transparency the condition used to be spoken of as "hyalitis," or inflammation of the vitreous; in such cases, however, it is probably merely the receptacle of inflammatory products given off by adjacent structures. That this is so in the case of the inflammation following perforating wounds has been shown by Pagenstecher, who found that the most irritating substances could be introduced into the vitreous without producing any reaction, provided that care was taken to prevent them coming in contact with the investing tunics by passing them through capillary tubes.

Purulent infiltration of the vitreous ("suppurative hyalitis") is most commonly the result of direct perforating wounds by septic instruments, but it may occur from the extension of purulent irido-cyclitis following injuries or operations. It also occurs in pyæmic conditions with septic embolism of the choroid. The vitreous rapidly becomes turbid, and then gives a white reflex from the pupil. As a rule there are at first marked inflammatory symptoms, with great pain, and occasionally pus is formed, which makes its way through the tunics, or reopens a wound. Much more commonly, in non-traumatic cases, the inflammation subsides and the eye begins to shrink. In such an eye the vitreous will be found converted into a tough, dirty grey substance, into which vessels can often be traced, and which contains an abundance of leucocytes and micrococci.

Floating opacities.—Chronic inflammatory processes in the tunics of the eye lead to the formation of floating opacities in the vitreous. Thus they occur in progressive myopia and in choroiditis from any cause. Such opacities vary much in size and form; they can generally be recognised with the ophthalmoscope as dark bodies which, when the eye is moved, are seen to continue their movements after it has come to rest. When they are situated far forwards they are best seen by using a convex lens behind the sight hole of the mirror. Sometimes these anterior opacities, if of large size, reflect light from their surfaces, and by focal illumination are seen to be greyish-white.

Sometimes a layer of extremely fine opacities is present in the anterior part of the vitreous; the opacities are so exceedingly minute that they may easily be overlooked, and the slight blurring of the margins of the optic disc thus produced is not unfrequently mistaken for neuritis. They can only be seen by holding the mirror close to the eye, and placing a strong convex lens (10 D) behind it. It is advisable to use a feeble illumination, that obtained from a plane mirror being best. The appearance is not unlike that of a fine gauze veil. These "dust-like" opacities are usually the result of syphilis.

Membranous opacities are occasionally seen in the vitreous; their formation is generally preceded by the presence of floating opacities, which prevent them being seen in their earlier stage. When fully formed they present the appearance of glistening white bands stretching across the fundus; often vessels can be traced a short distance upon their surface. The distance of these opacities from the retina can be estimated by seeing what parallactic movement they undergo when the observer alters his position, and by the strength of the convex lens with which they can be seen; each dioptre corresponding to about 0·3 mm. Sometimes these membranous opacities are mistaken for detachment of the retina; if a good view can be obtained, the mistake ought not to occur, as the opacity presents a much more glistening appearance, it has not the wavy appearance of a retinal detachment, and the vessels when present are straighter and less numerous. If, however, the white area is only imperfectly seen, owing to its extremely peripheral situation, the presence of other opacities, or partial closure of the pupil, it may be impossible to discriminate between the two conditions.

The coarser opacities of the vitreous are hardly ever amenable to treatment. It is true that Von Graefe* in such a case tore through a membranous opacity with a good result; it must, however, be very seldom that such a proceeding would be possible, and, if possible, desirable. The co-existence of other opacities, the probability of new ones forming in consequence of the inflammation excited by the operation, the probability that the affection which led to the formation of the opacity may have impaired the function of the retina, and, above all, the fear that an inflammation which has long been quiescent may be again aroused and endanger the safety perhaps of the sound eye, are all cogent reasons for a general rule of non-interference in such cases. "Let sleeping dogs lie" is an axiom which might with advantage frequently guide our conduct in the surgery of the eye. Recently this operation has, however, been repeated in several cases with encouraging results.*

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* *Arch f. Ophth.*, ix., ii, 102.

For the removal of the finer opacities in the vitreous the subcutaneous injection of pilocarpine has proved of some service. Two minims of a five per cent. solution may be used at first, and the dose be gradually increased. The immediate effect is the production of a profuse diaphoresis, which is often accompanied by nausea and vomiting, and followed by headache. The injection should not be made soon after a meal; about two hours after breakfast is a good time. The treatment is exceedingly irksome to the patient, and has to be continued many weeks; the results have, however, in many cases been sufficiently good to justify perseverance. Some patients are very susceptible to the action of pilocarpine, and the increase in the amount injected should therefore be very gradual. Iodide of potassium has sometimes proved of service, and it may be given in conjunction with the injections. When there is any ground for suspecting syphilis, a prolonged course of iodide of mercury is likely to be beneficial.

When the opacities are due to progressive myopia, treatment must be directed to the removal of all causes and conditions likely to favour its further increase.

Sparkling synchisis is a condition of the vitreous which is somewhat rare, but easily recognised.

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* Stedman; Bull. Tr. Amer. Oph. Soc., 1888.

It derives its name from the striking appearance it presents when viewed with the ophthalmoscope. This is produced by the presence within the vitreous of a large number of minute, almost uniform, plates of cholesterin, which either give a silvery white reflex, or, when partially transparent, have a golden appearance. They appear to be about half a millimetre in diameter, sometimes smaller, and occasionally larger, but are of course much magnified. When the eye has been at rest a few minutes, none, or only a few, may be visible, but after movement they are to be seen floating about in large numbers, often having that ill-defined direction of movement with which we are familiar in the flakes of a snowstorm. This condition only arises in those who are past middle life, and the impairment of vision is by no means so great as might at first have been supposed from the number of the floating particles. Both eyes are usually affected, although the appearances may be more marked in one than in the other.

We are indebted to Poncet for an account of the morbid anatomy of this disease.* In a pair of eyes thus affected he found the following changes: (1) Crystals of cholesterin in the form of minute plates; (2) acicular crystals of tyrosin, formed in many cases on fissures existing in the preceding (both these were soluble in ether); (3) highly refractive spherical bodies, some free, others aggregated, and others, again, coated with fine needle-like crystals looking not unlike chestnuts with their outer green shell on (the latter were unaffected by ether, but dissolved in nitric acid); (4) there were many cells with large nuclei, of various sizes, but all containing pigment, and many coated with phosphates. The stroma of the choroid presented here and there white globules, but the patient had died of pyæmia, and these may have been connected with that affection. In the region of the ciliary processes the choroidal epithelium presented a true colloid degeneration. The changes are described with great minuteness, and the microscopical appearances illustrated by drawings.

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* *Annales d'Oculist,* p. 235; 1876.

Another condition which may to some extent be looked upon as degenerative in character is undue fluidity of the vitreous. It occurs in high and progressive myopia, probably owing to the increased capacity of the globe not being accompanied by a corresponding growth of the true substance of the vitreous. It may follow hæmorrhage into the vitreous, or inflammation of the uveal tract, or may exist simply as a form of senile degeneration; indeed, some increase in the fluidity of the vitreous is the normal condition in advanced life, and predisposes to an escape of vitreous in the operation of cataract extraction. After any loss of vitreous the deficiency is supplied by a watery fluid.

Hæmorrhage is not an unfrequent cause of opacities in the vitreous. The source of the blood is usually the vessels of the ciliary processes, but it may come from the choroid, and even, in rare cases, from a retinal vessel. If extravasated in large quantity, it will be found impossible to obtain any fundus reflex, and this, together with the suddenness of the loss of vision, will establish the diagnosis. If the blood extend far forwards it may be possible to see it by focal illumination. Smaller hæmorrhages are seen with the ophthalmoscope, either as black patches against the red glow from the fundus, or, if partially translucent, as having a dark red colour. All hæmorrhages into the vitreous become darker in a short time. Sometimes, when extensive hæmorrhage has occurred, the blood forms a large clot, which is freely movable in the vitreous chamber, coming forwards and being visible by focal illumination when the patient looks downwards, and again rolling out of sight when the eyes are turned upwards. The blood is absorbed very slowly, and leaves behind either films of fibrin, or floating opacities containing some of the colouring matter of the blood.

The most common cause of the hæmorrhage is a blow with a blunt body, but it may be due to changes in the blood, or degeneration of the walls of the vessels. Occasionally, like hæmorrhage into the substance of the retina, it occurs in young and apparently healthy subjects. In such the bleeding is copious and situated far back; there is generally a history of constipation, and frequently the patient himself, or one of his parents, will be found to have suffered from epistaxis.* The source of the blood in these cases is believed to be the retinal vessels.

The prognosis in cases of extensive hæmorrhage is extremely unfavourable; absorption is generally slow and often imperfect; the proper vitreous substance is not replaced; and as absorption takes place, either the vitreous becomes unduly fluid, or owing to diminution in its amount the intra-ocular tension is lowered and detachment of the retina results. In cases of spontaneous origin, moreover, there is a great probability of a recurrence of the hæmorrhage in the same eye, or of a similar attack in the other.

The prognosis is of course most favourable in young subjects, in whom, however, spontaneous hæmorrhage is very rare. Occasionally the blood appears to be absorbed with marvellous rapidity. Thus De Wecker† has recorded the case of a medical student who suddenly lost the sight of one eye while walking in the street. The ophthalmoscope showed an abundant hæmorrhage into the vitreous, which extended sufficiently far forwards to be visible by focal illumination. Fifteen days later the vitreous was quite clear. The patient stated that he had had a similar attack previously, and that he had recovered completely in a few weeks.

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* Eales, *Birmingham Medical Review*, 1880; Trans. Internat. Med. Congress, 1881; Abadie, *Annales d'Oculist*, p. 36; 1886.

† "Thérapeut. Oculaire," p. 509.

The same writer* has described in the following words a partitioning of the vitreous by transparent membranes, which he believes to be due to hæmorrhage from the vessels on the optic disc:

"In several patients who stated that the sight of the affected eye had become suddenly extinguished, I have seen very thin transparent membranes extending from the slightly excavated and atrophic papilla through the whole vitreous, producing an appearance as if the latter were divided into nearly equal segments by membranous partitions, which were directed upwards, upwards and inwards, and downwards and outwards, respectively. In one case, which was a long time under observation, the membranes presented an appearance not unlike the half unfolded wings of a butterfly, and were limited to the inner third of the vitreous, while in the remainder no opacity of any kind was visible. The arrangement of these membranes reminded one of the Y-shaped segmentation sometimes seen round the central canal when the vitreous has been hardened. They were so transparent that they could only be seen by reflected light in the direct opthalmoscopic examination in certain positions of the eye. A patient aged sixty, who a year previously had suddenly lost the sight of one eye, had a second attack of hæmorrhage into it. The membranous opacities were seen arranged as above described, the disc was atrophic, and there were small flocculent masses in the lower and inner segment of the vitreous. It seems to me a natural inference to draw that the flood follows the course of least resistance along the lines of cleavage of the vitreous and gives rise to membranous thickening."

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* "Handb. d. ges. Augenheilk," iv. p. 688.

The treatment of a case of hæmorrhage into the vitreous must be directed to the avoidance of anything tending to increase the flow of blood to the eye. Absolute rest in a dark room should at first be insisted on, and for a long time all close work, stooping, and straining must be prohibited. Pressure carefully applied by means of a bandage and pad might be of service, or, if the case were seen immediately, the application of iced compresses would tend to arrest the bleeding. The application of Heurtleloop's artificial leech to the temple is thought by some to diminish the risk of immediate recurrence of the hæmorrhage, and it might be followed by the application of cold. The presence of cardiac or renal disease should be carefully inquired into, and the blood examined for deficiency of red corpuscles in every case of spontaneous intra-ocular hæmorrhage.

Blood-vessels are in very rare instances, and probably only as the result of inflammation, developed in the vitreous. In disorganised eyes in which the vitreous has become converted into, or is replaced by, an opaque solid mass, vessels from the retina and ciliary body sometimes extend some distance into it, and they are often seen upon membranous opacities. The cases now referred to, however, belong to neither of these classes, for in them the vessels project into the vitreous unsupported by any visible adventitious membrane. The earliest case of this kind is one which has been recorded by Coccius.* The external appearance of the eyes was normal. Ophthalmoscopic examination showed the vitreous to be infiltrated throughout with punctiform floating opacities, and to be in great part fluid. At the fundus were seen a number of vessels which, in the different positions of the eye, moved to and fro. These were most developed in the right eye, in which the longest reached forwards to the middle of the vitreous, where it ended in a long white thread which was lost in the upper part of the humour. Towards the lower and inner part of the vitreous such threads were observed coming from several shorter vessels, which after careful inspection were identified as capillary loops. When the eye made quick movements the observer could see, moving in small curves, vessels which, when the eye was at rest, appeared to be lying on the retina. The retinal veins were remarkably tortuous, and in many places concealed by turbidity of the membrane. Later on the vitreous cleared to some extent, when the new vessels could be seen to arise, some from the arteries and others from the veins of the retina, in the neighbourhood of the optic disc.

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* Quoted by Zander in his work on the ophthalmoscope; translated by R. B. Carter.

In Jaeger's atlas (Plate XV., Fig. 72) is an illustration of a case in which in one eye were several minute vessels, which arose from the disc, and, passing forwards into the vitreous, formed loops and returned; in the other eye there was a moderate degree of retinitis, but no development of vessels.

In a case which the writer saw under the care of Mr. Waren Tay at the Royal London Ophthalmic Hospital, the vessels sprang from a peripheral part of the retina. At the lower part of the fundus was a group of exceedingly minute, tortuous vessels; they coursed upwards into the vitreous in an irregular wavy manner, then each formed a loop and returned. At the summit of the loop was a slight thickening, which in several could be seen to consist of closely-packed spiral turns of the vessel. A few appeared to end in free extremities. Later on the vitreous became too cloudy for the vessels to be seen; it then again cleared, and three months after I first saw the case the conditions appeared unchanged.*

Up to the present time but few cases have been recorded of vessels having been seen in the vitreous during life, but from the frequency with which they are developed in disorganised eyes, and from what occurs in other non-vascular tissues, it seems not improbable that the rarity really consists not in the development of the vessels, but in the vitreous remaining sufficiently clear for them to be visible.

Cysticerci in the interior of the eye are very rare indeed in this country, but much more common in Germany, Von Graefe stating that he has seen 80 cases in 80,000 patients. The parasite appears to lie at first between the retina and choroid, then to perforate the retina and enter the vitreous. The ophthalmoscopic appearances are so striking that the diagnosis is not difficult. The cyst presents a globular, somewhat glistening surface ; the head, a small tapering process with a slight enlargement at its extremity, is alternately protruded and retracted, and the vesicle undergoes slight tremulous movements on slight motion of the eye. A cysticercus always leads eventually to loss of the eye, either by the vitreous becoming opaque, by suppuration taking place, or by the globe shrinking. Von Graefe has succeeded in removing the cyst by first extracting the lens, as in an ordinary operation for cataract, and then drawing out the cyst with a blunt hook. They have also been successfully removed through a sclerotic incision.

"**Pseudo-glioma.**"—As the result of inflammatory changes, a condition of the vitreous is produced which sometimes goes by this name because the condition is not unfrequently diagnosed as glioma of the retina. This condition seems to occur chiefly in young children who are badly nourished, and is characterised by degeneration and shrinking of the vitreous, which is converted into a solid, dirty-white, opaque substance. The shrinking leads to diminution of the intra-ocular tension, and to retraction of the periphery of the iris; two circumstances which aid in establishing the diagnosis between glioma and the so-called pseudo-glioma. In the former affection there is always increased tension at some period of its growth, although the date of its onset is variable. In glioma also the lens is pushed forwards, but there is no retraction of the iris periphery, so that the anterior chamber is shallow, and the iris forms an inclined plane from its periphery to the pupil. In pseudo-glioma, on the other hand, the depth of the anterior chamber is only slightly, if at all, diminished, and the plane of the iris presents a shallow groove or trough round its peripheral portion; the reflex from the pupil is, moreover, less brilliant than in the glioma, and in the latter vessels can generally be seen on the surface of the growth.

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* This case, together with two others, will be found fully reported in the Ophthalmic Hospital Reports for June, 1881.

Detachment.—As already stated, progressive myopia is liable to be complicated with opacities in the vitreous. Another complication, which is, however, extremely rare, or rarely recognised apart from detachment of retina, is detachment of the vitreous. In a case described by Dr. Brière* the surface of the detached portion was visible as a greyish film covering the disc, but lying considerably anterior to it, and shading off gradually at its margins. The patient was a myope of eleven dioptres, whose eyes had recently been subjected to unusual and prolonged strain. The condition remained stationary for two months; some improvement in vision then took place, and the opacity became less dense, and five months later nothing abnormal could be seen.

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* *Annales d'Oculist,* p. 138; 1875.

Foreign bodies.—The vitreous chamber is not unfrequently penetrated by foreign bodies; usually these are of small size and metallic, the most common being fragments of steel or iron which have flown off a hammer or chisel. The choice of the line of treatment to be pursued in a case of wound of the vitreous depends so much on what other structures have been wounded that it will be more conveniently discussed in chapter xii.; in this place it will be sufficient to indicate the local results which may follow the lodgment of a foreign body. If the eye be examined a few hours after the injury the intruder may be visible with the ophthalmoscope, surrounded by a halo of opacity or cloudiness; but if the wound has caused hæmorrhage into the chamber, or if some days have elapsed since the receipt of the injury, it is generally impossible to examine the vitreous. Very soon the whole medium becomes turbid, owing to the presence of innumerable floating opacities, the halo around the foreign body becomes denser, and, if the vitreous be sufficiently clear, a fine white streak can often be seen connecting it with the point of entry. Later on the foreign body may become completely encapsuled, while the remainder of the vitreous may clear. This represents the most favourable condition that can result, and it may persist for an indefinite time. Such a result is, however, exceptional; more often the cicatricial band connecting the foreign body with the seat of the wound, undergoing contraction, causes the retina to become detached. Suppuration may take place around the foreign body, and lead to disorganisation of the whole vitreous; or it may be localised, in which case, as the pus becomes absorbed, the walls of the abscess fall together, and detachment of the retina may be produced by the traction. Even cases in which all inflammatory symptoms have long subsided are not free from danger, for fresh attacks may be lighted up at any time, sometimes without any obvious cause, and may lead to irido-choroiditis, opacities in the lens and vitreous, shrinking of the globe, the loss .of the other eye from sympathetic inflammation. In some of these cases the mischief seems to have been started by the foreign body, which was previously encapsuled, having been set free.

Sympathetic trouble is especially to be feared if the injured eye remain tender to the touch; indeed, as long as this symptom persists no lapse of time from the receipt of the injury will put the eye beyond danger. The following case, recorded by the late Mr. Soelberg Wells, well illustrates this:

"J.K., æt. 42. The left eye had been wounded 26 years previously by a piece of metal, the globe had shrunk to a fourth part of its natural size, and was extremely tender on pressure. The right eye had remained unaffected till seventeen years after the accident, when it was attacked by iritis, and an iridectomy was performed. It then continued well for eight years longer, when it again became inflamed, and the sight failed more and more. Fourteen months later it was in the following condition: cornea somewhat hazy, iris inflamed, and pupil closed. Visual field not contracted, but patient could not read 20 Jaeger. The left eye sunken and tender; this was enucleated, and a piece of metal was found imbedded in it. Four days later the sight of the right eye had improved to 16 J. and three weeks later to 10 J. Six months after the operation the patient wrote, stating that he was following his employment as superintendent of an iron forge."*

Wounds of the vitreous have occasionally been followed by the entrance of air. Two such cases have been recorded by Mr. Stanford Morton,† and the writer has seen a similar instance in the practice of Mr. James Adams. In this case a young man had been struck in the eye with a fragment of metal, which inflicted a wound behind the ciliary region downwards and outwards. At the lower part of the fundus was a layer of extravasated blood of triangular shape, having its apex directed upwards; a little above its apex, and lying on the retina, were three air-bubbles; each had a diameter of about a quarter of that of the optic disc, and presented a bright central spot surrounded by a dark ring. They lay in contact with each other, and rolled slightly upon one another when the eye was moved. The magnet afforded no evidence of presence of a metallic foreign body, and the case recovered completely.

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* *Lancet*, Dec. 18th, 1869.

† Ophth. Hosp. Reports, 1879.

W. A. F.

CHAPTER VIII.

GLAUCOMA, PRIMARY AND SECONDARY.

THE word "glaucoma," like the word "cataract," is now only a survival from a period when neither the nature nor causes of the condition so named were understood, and when the greenish tint oftentimes displayed by the pupil was regarded as an entirely characteristic appearance. In modern parlance "glaucoma" is a generic term used to denote a state in which the tunics of the eye are overfilled and distended, and in which the contained structures are suffering from the pressure to which they are exposed. By "primary" glaucoma we signify cases in which the increase of fulness is the first noticeable symptom; by "secondary," the cases in which distension is a consequence of some manifest preceding change.

In the directions already given for estimating tension, as part of the general examination of the eye (page 86), it has been stated that a certain degree of fulness is required in order to preserve the proper curvatures of the boundaries of the several refracting media, and the right distances between the different parts of the eye. This normal degree of fulness, or, as it is technically called, of "tension," is a result of the balance between the constant secretion of fluid within the chambers and its constant removal by absorption or exhalation. The high tension of primary glaucoma is probably always a consequence of checked exhalation; the high tension of secondary glaucoma may frequently be a consequence of hypersecretion.

The exhalation or escape of fluids from the interior of the eye probably occurs through many channels; but it has been shown by modern research that the most important of these is furnished by the comparative laxity or porosity of the "filtration area," the annulus of tissue immediately posterior to the margin of the cornea and anterior to the ciliary margin of the iris. This annulus is traversed by Schlemm's canal, with its contained plexus of veins, which are, in all probability, the chief agents in carrying away any superfluity of liquid.

The fluid withdrawn from the eye through the filtration area must, of course, be immediately derived from the anterior chamber; but its withdrawal permits more to pass through the pupil from the posterior chamber, and this, again, will be reinforced from the vitreous body through the hyaloid membrane and zonule of Zinn; so that free filtration in this single region suffices to relieve all the cavities of the eye.

In order that filtration may be rapid and complete, it is manifestly necessary that the access of the fluid in the anterior chamber to the filtration area should be easy; and this condition is only fulfilled when the posterior surface of the outer tunic, and the anterior surface of the peripheral part of the iris, meet in such a way as to form an open angle. If the peripheral zone of iris be pushed forward so as to close or to diminish this angle, and, still more, if the peripheral portion of the iris be applied like a valve to the portion of the outer tunic immediately in front of it, filtration must be either greatly checked or altogether arrested.

The researches which have been made with regard to dialysis, or the transudation of liquids through animal membranes, have shown that these membranes, without undergoing any obvious change, may yet come into a condition in which transudation is no longer free, and in which the membranes themselves are said to be "pectous." It has always seemed to me probable that a pectous condition of the external ocular tunic in the filtration area may be the first link in the chain of morbid sequence which constitutes glaucoma. The disease seldom commences until a time of life when the period of degenerative changes is at least approaching; and it is quite possible that such changes may place impediments in the way of transudation. According to some writers, the bulk and position of the crystalline lens are important factors, and Mr. Priestley Smith has assigned as a cause of glaucoma the increase in the magnitude of the lens which he has shown to occur in advancing life. Glaucoma is certainly more frequent in hypermetropic eyes than in others, and especially in hypermetropic astigmatism; so that continued strain of the accommodation may also be an element in its causation. Of the causes yet assigned, however, scarcely one is in any practicable sense remediable; and all leave the surgeon face to face with the necessity of submitting the disease to treatment when it occurs.

Whatever may be the first link in glaucoma, a small increase in the amount of fluid contained within the eye becomes at once a cause of further and continued increase. Almost the first effect of the small increase is to push forward the periphery of the iris, so as to narrow the angle between the sclero-corneal ring and the iris, and to check the free access of fluid to the filtration area. At the same time the lens is pushed forwards, and, by protruding through the pupil, dilates it, thus still further thickening the base or periphery of the iris, and tending still more to produce closure of the angle. As these two actions continue, the iris may even become applied to the filtration area so as to act the part of a valve, and almost entirely to forbid the access of aqueous humour to the region through which it might escape most readily from the eye. By the time, or before the time, when this condition is reached, the distension of the globe must already be considerable, and may be sufficient to compress, and partially to close, the oblique channels through which the venæ vorticosæ pass outwards; so that, while the arteries are still free to introduce blood, subject only to the increased resistance offered by the fluid in possession, the outlets through the veins are seriously impeded.

The consequences of the pressure thus exercised are shown in various ways: first, upon the sensory and motor nerves and the blood-vessels, soon upon the optic nerve, sometimes upon the tunics and general nutrition of the globe, and, in all cases, ultimately upon the retina.

The sensory and motor nerves of the eye, which proceed from the ophthalmic ganglion and pierce the sclera in the vicinity of the optic nerve, pass forward between the sclera and the choroid to reach the ciliary body. When the eyeball is too full, these nerves are compressed against the unyielding sclera, and the first effect of the compression is to diminish their functional activity. The first to suffer is usually the motor nerve of the ciliary muscle, and hence the power of accommodation fails more rapidly than the age of the patient will explain. When a person in middle life wants to have stronger reading spectacles every few weeks or months the approach of glaucoma should be suspected. It is a tradition of old standing among spectacle-sellers that glasses which are "too strong" are hurtful; and this presumably rests on the observation that customers who have insisted upon obtaining stronger and stronger glasses at short intervals have usually become blind at no very remote period.

The participation of the sensory nerves is usually shown by impaired sensibility of the cornea, which may often be touched by the finger-tip without any reflex action being produced.

In the meanwhile, when fluid is continually forced into a closed cavity, the part of that cavity which possesses the smallest power of resistance must give way; and in the eye the part in question is the surface of the optic nerve. This surface becomes pushed back, until, in extreme cases, it recedes to the plane of the lamina cribrosa, and the nerve is said to be excavated or cupped. The retinal arteries and veins, being carried back with the nerve surface, become bent at a sharp angle around the edge of the scleral foramen; and, as the entrance and exit of blood are alike impeded, the arteries are comparatively small and pale, the veins tortuous and distended. At the same time, and even before cupping is carried to any great extent, a conspicuous pulsation often appears in the retinal veins upon the disc; and this pulse, if not existing, may often be developed by a very small amount of finger pressure. At a still later stage the arteries also may pulsate.

The pulsation of the distended retinal veins of glaucoma is so conspicuous a phenomenon as to be readily seen in the inverted ophthalmoscopic image; and at one time great diagnostic importance was attached to it. Since the use of the erect image, with its better illumination and greater enlargement, has become almost universal, it has become known that a retinal venous pulse is by no means uncommon in the healthy eyes of young people; but still, the physiological venous pulse may without much difficulty be distinguished from the pathological one. The former is a mere rhythmical wave of varying fulness in the largest vessels, probably due to a momentary forcing back of their contents by the impulse of the arterial blood-current; but the latter is much more than this, and, although somewhat analogous in its essential nature, usually extends even to the smallest vessels of the disc, and in such a degree that the blood is driven out of the veins from the centre of the disc towards its circumference, and returns again from the circumference to the centre, the disc being manifestly bleached during the interval. Pulsation of the retinal arteries occurs only in an advanced stage of eyeball hardening, and appears to denote that blood can only enter at the acme of the pulse-wave, instead of, as usually in a vessel the size of the retinal artery, in a continuous stream. Apart from glaucoma, however, arterial pulsation has been witnessed in some cases of extreme arterial tension, and in some of mitral insufficiency.

While such is the state of the retinal circulation, that of the choroid is affected in a similar manner, and the distension of the veins seeks relief through the small vessels which perforate the sclera near the corneal margin and course backwards beneath the conjunctiva. These veins in glaucoma become distended and tortuous, and clearly point to the existence of some impediment to the circulation in the system from which they spring.

In advanced stages of the disease the pupil becomes more dilated, and generally assumes the shape of an ellipse with its major axis horizontal. At the same time the nutrition of the corneal epithelium is disturbed, and the surface of the eye may display a steamy aspect, something resembling that of glass which has been breathed upon.

As the degree of internal pressure increases the retina is at first rendered torpid by compression, and ultimately becomes disorganised or atrophied. These changes commence at the periphery, the portion most remote from the centre of the blood supply, and usually first on the temporal side, so that the nasal side of the field of vision is the first to suffer. As the periphery of the retina becomes more and more compressed, the field undergoes contraction in every direction, but usually more towards the nasal side than elsewhere. At the same time the conducting fibres, which, together with the retinal blood-vessels, become sharply bent around the edge of the sclerotic foramen, are like these exposed to injurious pressure, and are apt to undergo atrophic changes in consequence. The aggregate result of long-continued high tension is to involve all the contained structures of the eye in one common ruin, and to entail hopeless blindness upon the patient.

The actual symptoms presented by glaucoma will vary greatly with its acuteness; that is to say, with the rapidity of increase of the tension. If this be very slow, so that the sclera has time to accommodate itself to the increasing pressure, pain will hardly be experienced, and no active irritation will be produced. The eye will be a little hard, the optic nerve a little shallowed out and pallid, and sight will slowly fade from the periphery of the field to the centre, but with a gradual and almost imperceptible decadence.

If the case be a little more acute, that is, if the obstruction to filtration be more sudden, the tension will be likely to rise by sudden increments, each one of which will be attended by a sensible increase in the obscuration of sight. After a few days the obscuration may to some extent subside, and the patient will often profess to see better, but he will not return to the degree of acuteness of vision which he possessed before the last attack. Each one will leave the vision something worse than it was before. This form is commonly called "subacute," and it is apt to terminate in an attack more severe than any which has preceded it, and by which sight is finally extinguished.

The "acute" form runs a course somewhat more rapid than the foregoing, with fewer attacks and shorter intermissions; and the increments of tension are frequently sufficient to cause severe pain by distension of the sclera, together with sharp inflammatory reaction. Such cases are very liable to be mistaken by inexperienced practitioners for "gouty" or "rheumatic" inflammation, and to be treated in some inefficient and useless manner, until the time at which a cure was possible has passed away, never to return. In the most acute form, which was described as "fulminating" by Von Graefe, the onset is sudden, the pain intense, the loss of sight complete from the beginning of the attack, and the period of time available for treatment is extremely short.

Besides the symptoms already mentioned incidentally, patients in whom glaucoma is impending are apt to complain of seeing rainbow colours around candle flames or other forms of artificial light. Beyond this they seldom give a clear account of their own symptoms, and the facts must be obtained from them by careful inquiry. A common type of case is that an elderly person seeks advice on account of failing sight, after having more than once obtained stronger and stronger spectacles, which soon cease to be useful. The pupils are sluggish, rather dilated than contracted; the irides pushed forward, rendering the anterior chambers shallow; the subconjunctival veins which emerge from the eyeball more distended than in health. The patient will say that dark clouds have occasionally passed before the eyes, obscuring the sight for a time and then clearing away, lasting from a few minutes to some hours. Sometimes one or both corneæ will look as if they had been breathed upon, in which state the background of the eye can only be seen imperfectly, and the sight is likely to be so defective that no accurate tests can be applied to it; but where the corneæ are still clear, the ophthalmoscope will show the optic disc to be depressed into a cup or excavation, the floor of which, being more remote from the observer than the margin, will require a weak concave lens behind the mirror for its perfect definition by the direct method, in cases where no lens is required for the margin of the cup. The sides are sometimes so steep, and the vessels follow them so closely, that the latter appear cut off at the margin; and their continuations on the depressed surface, being out of focus when the margin is distinct, will appear hazy, but can be brought into clearness by the use of an appropriate lens, which will render the margin indistinct in its turn. The difference of level between the margin and the floor of the depression may thus be measured, the observer estimating that each dioptre of lens power required for the deeper part implies about one-third of a millimetre of actual depression. Such a "pressure cup" must be carefully distinguished from the physiological excavation which is described on page 297. In cases of long standing the disc is often surrounded by a white halo, caused by atrophy of the choroid over a limited area. Venous pulsation will generally be visible, or, if not, may be produced by slight digital pressure. The field of vision will invariably be found deficient, and the deficiency may either be limited to the nasal side, or more conspicuous and more extensive there than elsewhere. Palpation, conducted in the manner described on page 80, will afford definite evidence of hardness or increased tension. Of the foregoing symptoms, it may fairly be said that two, *i.e.*, increased tension and contraction of the field, are never absent, and that their presence is alone sufficient to determine the existence of glaucoma. No case of failing vision, whether attended by apparent "inflammation" or not, has been adequately examined until the presence or absence of morbid tension has been determined.

The only permanently successful treatment of glaucoma is by operation, and there is one negative precept which cannot be too strongly impressed upon the memory, this is, never to use atropine or belladonna in any form. Just as a zinc lotion may convert a trivial case of iritis into one of extreme severity, so the application of atropine to an eye threatened with glaucoma may produce an almost fulminating outburst, and, unless a skilful operator is at hand, may in a few hours destroy every hope of sight. The effect of atropine is to diminish the calibre of blood-vessels, and, so far, it would seem calculated to diminish tension; but its effect in this direction is far more than counterbalanced by the dilatation of the pupil, which, by drawing the iris into a thick zone close to the filtration area, prevents the ocular fluids from gaining free access to the region at which they might find an outlet.

On the other hand, we possess in eserine an agent which, although it dilates blood-vessels, acts much more powerfully by contracting the pupil, and thus drawing the iris into a horizontal plane away from the filtration area. The application of eserine speedily lowers tension, and for this purpose a solution of two, or even of four, grains to the ounce of distilled water appears in front of the iris, the direction of the thrust, so far, being towards the centre of the eyeball. As soon as the point appears the direction is changed, the point being thrown forwards by a backward inclination of the handle; and the blade is pushed steadily on, care being taken that its point rides over the lower margin of the pupil, while at the same time it must not be sufficiently directed forwards to touch the cornea. The operator, during this part of the thrust, should keep his eye fixed on the inferior pupillary margin as the landmark by which to guide his course. When the point is safely over this, the thrust should be continued in the same direction until the knife approaches the other side of the anterior chamber, or until the length of the wound of entrance is sufficient. If the blade have parallel sides, and if these are fairly engaged in the incision, the latter will be of equal length within and without; but, if the sides of the blade are angular, it will often be desirable to enlarge the internal wound by a slight lateral inclination of the blade as it is withdrawn. The withdrawal should be effected quickly, but very steadily and gently, so as to avoid any jerk, which might throw the lens against the retreating point.

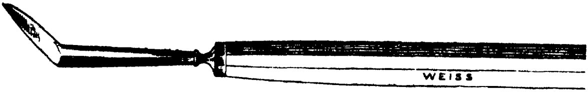

Fig. 49.—Iridodesis Knife.

When the iris and lens are much pushed forward, and the anterior chamber is very shallow, the manœuvre described above will not be practicable, and some different method of making the incision must be adopted. One such is to select the very narrow bent knife usually called an iridodesis knife (Fig. 49), and to fix the eye close to the left-hand extremity of the intended incision. The knife is introduced immediately on the right of the forceps, and its point carried between the cornea and the iris nearly to the pupillary margin. Its right-hand edge is then made to divide the tissues against the traction of the forceps until an incision of adequate length is obtained. Another method is to use a cataract knife, and to puncture and transfix as for extraction, taking care that the knife is kept between the cornea and the iris, so that its point does not enter the area of the pupil.

The incision being completed, the surgeon introduces the forceps and draws out a vertical fold of iris as in cataract extraction, but completes the excision in a different manner. He first cuts completely through the iris, from its pupillary to its ciliary margin, at the right-hand angle of the wound. By means of the forceps, he tears the portion held by them from its ciliary attachment, up to the left-hand angle of the wound, and there cuts it off close to the eye, pushing back the outer tissues with the scissors, so that the remainder of the iris may retract into the anterior chamber when the pressure is removed. If the retraction is not complete, any portion of iris entangled at either extremity of the wound must be gently returned into the eye by a fine spatula. The lids are closed with a pad and bandage, as after cataract extraction, and the after-treatment is of the same character.

The incision for sclerotomy is the same as for cataract extraction, except that its whole length should be outside of the cornea, and that the operator, after transfixion, uses the cutting edge of the knife with extreme caution, so as to divide the bridge of scleral tissue which intervenes between the punctures, but to leave the middle part of the bridge of conjunctiva uncut. The eye should not be bandaged, but the closed lids covered with a light moist compress, the object being to allow the scleral wound to gape as much as the undivided conjunctiva will permit. The iris is left untouched, but will sometimes undergo prolapse into the incision.

Assuming one eye to be affected by glaucoma, and the other to exhibit threatening symptoms, it is generally best to operate on both at once. The patient will have but one period of nursing or confinement, and the only drawback to the double operation will be the period of complete helplessness which has to be passed through while both eyes are bandaged, and, in a less degree, before either is restored to actual utility.

The prospects of ultimate and permanent recovery in glaucoma are generally greater in the acute cases than in the chronic. In the latter the march of events is often so insidious that the best time for treatment is suffered to pass away, and there is often a tendency on the part of the long-compressed and injured nerve to lapse into a state of atrophy, sometimes with, sometimes without, a short interval of improvement. In favourable cases, however, where the excavation of the disc is not too deep, and the disease not of too long standing, the surgeon may generally reckon upon arresting the morbid process at the point which it has reached, and upon preserving nearly or quite all the vision that remains. Even in the worst cases the operation should be performed; because, if matters be suffered to take their own course, the termination in total and irremediable blindness is inevitable.

In acute cases, as in chronic, the best time for operating is often lost in consequence of sheer ignorance. Even in the present day, after a good many years of ophthalmic teaching in all the more important schools of medicine, it is marvellous to see the frequency with which cases of unrecognised glaucoma present themselves at hospitals and in private practice. Patients are told that the affection of the eye is "rheumatic," or that it is "gouty," and they are advised to submit to all kinds of treatment, external and internal, for the imaginary rheumatism or gout, while all the time an incurable blindness is coming upon them with steady steps. I have even met with instances in which practitioners have deprecated interference, and have succeeded in deferring the time at which skilled advice was obtained, on account of what they called the "inflammation," and in which they have proposed to reduce this "inflammation" as a preliminary measure. Any real or apparent inflammation which occurs in glaucoma is a result of the distension of the ocular tunics; and although such inflammation may subside after a time, when the tunics become used to the distension, the patient will be blind before that time arrives. Every day, and in acute cases every hour, that is lost before operation is resorted to will imperil, and may often destroy, every remaining hope of the restoration of sight. An operation upon strangulated hernia is not more urgently required for the preservation of life, than an operation upon acute glaucoma for the preservation of sight; and every surgeon who is qualified to undertake the one should also be qualified to undertake the other. If the practitioner who first sees the case is not himself prepared to operate, he ought, nevertheless, to be able to recognise the urgency, and prescribing an application of eserine as a temporary measure he ought at once to direct his patient to some one who will do what is required without delay. The results of a timely iridectomy in acute glaucoma are of unsurpassed brilliancy, and a patient who can barely discern light from darkness at the time of operation will patient who had been successfully operated upon, in both, for diabetic cataract, and who retained excellent vision for a year or more before the glaucomatous symptoms displayed themselves. They might possibly have been connected with the diabetes, but hardly with the opaque lenses or with their removal. A form of high tension after cataract extraction which may perhaps be called secondary is one in which the posterior capsule of the lens and the hyaloid membrane seem to become "pectous," and to oppose resistance to the passage of fluid from the deeper to the more superficial parts of the eye. When there is any tendency to rise of tension a few weeks after cataract extraction, or at any subsequent period, the first thing to be thought of is to tear through these combined membranes with two needles, used as if for the division of a capsular film, and thus to render the vitreous body continuous with the fluid in the anterior chamber.

In its more commonly received sense, however, secondary glaucoma follows prolonged irritation or inflammation of the cornea or iris, and occurs, in some cases of iritis, at quite an early stage, as I have already incidentally mentioned in speaking of one of the forms of the "serous" variety. The practical lesson to be learnt from this liability is that the practitioner should never omit to examine for high tension, should no more neglect to feel the eyeball in treating its diseases than he should neglect to employ the thermometer in fever or inflammation, or to test the urine before forming a diagnosis. Glaucoma is not less hurtful for being secondary; and the tissues of the retina cannot hold their own against excess of pressure. Whatever we may call the primary malady, if an eye be too tense, and especially if vision be declining, the tension must be relieved or vision will be lost. In many secondary cases, paracentesis, if combined with due watchfulness and repeated with adequate frequency, will be sufficient; but, unless its employment is followed by definite and progressive improvement, iridectomy or sclerotomy will be required. The young eye is more tolerant of high tension than the old, its tunics being more yielding; but it will not be safe to presume on this tolerance over much. I have seen very high tension follow excision of the centre of the cornea in the treatment of conicity, insomuch that a large iridectomy was required for the preservation of sight, and there was no time to wait to ascertain in what portion of the cornea it could be placed with the greatest advantage. It is possible in that case that the high tension was a result of the complete atropinisation of the eye.

It is highly necessary to be on the watch for glaucoma as a complication of other ocular maladies. In elderly people it is often associated with the commencement of cataract; and it is not sufficient, merely because opaque striæ may be present in the lens, to assume that they are the sole causes of the failing sight. The tension must be examined as well as the lens; and, if the tension be too high, iridectomy should be performed forthwith. The lens may not be ready for extraction for a year or more, but, whenever the time comes, the iridectomy is so much done towards the second operation; and if the diagnosis be correct and the operation successful, sight which would otherwise have been lost will be preserved.

When the diagnosis of glaucoma is uncertain, the tension perhaps a little high, but not excessive, and the sight not sufficiently modified, either in the centre or at the periphery, to call for immediate action, the only method is to watch the case closely with a view to future contingencies. The use of the perimeter becomes in such cases advisable, and a careful chart of the field should be preserved for comparison with one to be taken shortly afterwards. The disc margins should be most carefully scrutinised with the ophthalmoscope, and any vessel which exhibits a tendency to bending inwards at the margin should have its position and relations noted in a sketch or diagram, so that any increase in its curvature may be speedily detected. In the meanwhile a solution of eserine should be applied (for such conditions a weak solution, say of the tenth of a grain to an ounce of water, should be used four or five times a day), the eyes should as far as possible be relieved from any kind of arduous work, and the general health should be considered. A month or two will seldom fail to clear up the true nature of the case.

R B C

CHAPTER IX.

OPTIC DISC, RETINA, CHOROID, AND POSTERIOR HALF OF SCLERA.

Before entering upon the study of the morbid conditions of the background of the eye, it is necessary to be familiar with the anatomy of the structures which it contains, and also with the construction and management of the ophthalmoscope. The reader will find what is essential for these purposes in preceding chapters; but no amount of reading will supersede the necessity for examining the interior of the eye, whether healthy or diseased, as often as opportunities will permit. It is only by assiduous practice that the art of seeing with the ophthalmoscope can be fully mastered; and it is necessary to see clearly before beginning to interpret.

What is seen with the ophthalmoscope is a portion of the concave surface of a hemisphere, separated from the observer by the various refracting media, and, when these media are clear, seen as if they were non-existent, except for the degree in which they magnify the details. The surface presents the delicate and translucent retina, traversed by arborescent blood-vessels and supported by a richly coloured background of choroid; while the uniformity of the picture is broken at the posterior pole by the absence of vessels characteristic of the yellow spot, and, a little on the inner side of the pole, by the conspicuous entrance of the optic nerve, an object which, in the background of the eye, has been compared to the moon in stellar space. The healthy nerve may display many different aspects, most of which may be easily understood by reference to its anatomy.

The fibres of which the optic nerve trunk is composed, save in a few exceptional cases, leave their sheaths to blend with the connective tissue of the lamina cribrosa, and enter the eye alone, or at least accompanied only by blood-vessels. The fibres are in a high degree translucent, almost transparent, and the vessels consist not only of the trunk and branches of the central artery of the retina, and of the veins on their outward way, but also of a considerable capillary plexus, which gives to the nerve structure generally a more or less roseate tint. The lamina cribrosa, which closes the sclerotic foramen, is white and shining, and the interstices in its structure, through which the fibres pass, are dark by comparison, and generally appear to be of a somewhat bluish tint. When the cornea is sufficiently turned towards the nose to bring the nerve entrance into the middle of the field, the observer sees some indication of the inner edge of the sclerotic foramen, which bounds the margin of the nerve on its nasal side as a fine white crescentic line.

Surrounding the whole circle is the well-defined edge of the foramen in the choroid, and this foramen is often pigmented, sometimes all round, in other eyes at a part of its circumference only. The division of the arteries and the union of the veins are very variable. In some eyes we see a single arterial trunk, which, after its entrance into the globe, divides into upper and lower branches, from which many smaller ones proceed. In others the division occurs within the nerve trunk, prior to entrance into the eye. In some there is a considerable retro-bulbar division, and several branches enter, some in or near the axis of the nerve, others at its periphery. In all, the general ultimate distribution is the same, the larger branches bending in bold curves around the region of the yellow spot to reach the temporal side of the eye, while smaller branches bend in lesser curves towards the nasal side. The companion arteries and veins sometimes run a nearly parallel course, sometimes are curiously interlaced and twisted. The region of the yellow spot contains no large vessels, although fine twigs run towards it from every side.

The general aspect of the optic nerve is therefore that of a roseate or pinkish-white circle, set in the middle of a distinctly red or orange background, bounded by a fine white line upon its inner side, and, in many persons, partly or completely, by a ring of dark pigment outside this line. Within the circle the appearances vary with the method in which the different elements of which it is composed are packed and combined. As soon as they enter the eye, the nerve fibres bend round to be distributed to every part of the retina, and this bending often commences even in the trunk, so that the fibres separate somewhat from each other, after the fashion of the mouth of a trumpet or the corolla of a convolvulus, and leave a central vacant space, which has been called the "porus opticus." If this space be large enough and deep enough, it will reach down to the level of the lamina cribrosa, which will form its floor, and the whiteness of which will be conspicuous against the pink colour which the nerve fibres themselves derive from their capillary vessels. Hence when the distribution of the fibres is symmetrical, we see a central white spot, in which, if it be large enough, we may discern a bluish mottling, and which is surrounded by a pink or slightly rosy zone, composed of the actual nerve tissue. The arteries will often emerge from the porus, and the veins will sink into it, both, of course, crossing the surrounding rosy zone in order to reach the retina; but, when the porus is a comparatively small opening, the actual flexion of the vessels may be too abrupt to be easily followed. When the porus is comparatively large, with a considerable area of the lamina cribrosa for its floor, it is often described as a "physiological excavation of the optic disc;" and the vessels may be seen to bend round its margin, to descend its sides, and to reappear on the surface of its floor, requiring, as in the pathological excavation of glaucoma, different lenses behind the mirror in order to see them with equal clearness in all parts of their course. The physiological excavation, however, is always characterised by being surrounded by a zone or ring, however narrow, of rosy nerve tissue, intervening between it and the margin of the sclerotic foramen; while in the pathological excavation, which is produced by the yielding of the nerve as a whole to excessive pressure from within, the whole of the nerve tissue is depressed, and the pit extends quite up to the edge of the scleral foramen, from which it is separated by no intervening tissue. These different appearances are absolutely characteristic, and ought to prevent any possibility of an error in distinguishing between them.

In some eyes the porus opticus is so small as to be almost non-existent, and the central vessels emerge from an uniform level of nerve tissue. In others the distribution of the nerve fibres is not symmetrical. Sometimes they are massed together upon one side of the foramen, in others upon the other; but more frequently, I think, upon the nasal side. Such asymmetry produces a corresponding aspect, one portion of the disc being occupied by nerve fibres, while in another the comparative whiteness of the lamina cribrosa is exposed to view. In order to answer the question whether a given nerve surface is healthy, the beginner must ask whether its appearances are such as to be explained by any ordinary combination of the three elements, the lamina cribrosa, the nerve fibres, and the blood-vessels, which enter into its composition.

When the fibres are massed towards one side of the opening, the margin of the disc will in this portion be somewhat less clearly defined than elsewhere. Although translucent, the fibres are not perfectly transparent; and, where they are numerous, they will a little quench the perfection of detail which may be seen through them where they are scanty. It is, therefore, quite consonant with health that, when the fibres are massed on the nasal side, the boundaries of the disc on that side should fade almost insensibly into the surrounding retinal tissue, while on the opposite side the margin of the foramen may be sharply perceptible.

In health, the vessels which traverse the optic disc cross its margin in straight lines, and are always defined with perfect sharpness when the correct lens is behind the mirror. The veins are somewhat fuller and darker than the arteries, sufficiently so to be easily distinguished from them; but both are sharply defined, and the larger vessels, especially when they leave the disc, are marked by a central bright line, which is very conspicuous upon their red colouring.

Even the finest vessels which cross the disc margin should be defined with absolute clearness; and the very small twigs, which generally run horizontally towards the temporal side, afford excellent test objects for the determination of this character. Besides the central bright line, the larger trunks sometimes show lateral white lines, which accompany them for a short distance upon the retina, and appear to be nothing more than filaments of connective tissue, showing that the web of this material, by which the vessels and nerve fibres are supported, is in some eyes of a somewhat coarser texture than in others. The central bright line on the larger vessels is probably a reflection of light from the most prominent part of the surfaces which they turn towards the spectator. Excepting for this, all objects in the background of the eye are seen in their true colours.

In certain eyes the vessels which traverse the optic disc will appear to be somewhat blurred, and even the outlines of the disc itself to be indistinct. This appearance may be due to morbid conditions, but it may also be due to an error of refraction, the examined eye being either hypermetropic or myopic. The beginner must be careful to exclude the last-named conditions, by employing correcting lenses behind the mirror, before deciding that the want of definition is real. The best view attainable with a correcting lens is that which alone must be used for any diagnostic purpose.

We have, then, as the range of normal or physiological appearances in the optic disc, almost any conceivable distribution of the two main elements entering into its composition, that is, of the nerve fibres and of the meshes of the lamina cribrosa; a considerable variety of distribution of the vessels; a few white lines streaking the larger ones and extending a little beyond the nerve boundaries; more or less dark pigmentation around the margin; and a slight amount of quenching of the outline of this margin at any point where the nerve fibres pass over in considerable quantity into the retina. I think it may fairly be said that no two nerves are quite alike; and the learner will find it to his advantage to use all possible opportunities of examining them in healthy eyes, so as to become perfectly familiar with all ordinary variations. Until this has been done, the study of morbid appearances is, to say the least, premature; and it is much to be wished that in the wards of hospitals an ophthalmoscopic examination could be made as much a matter of routine as an analysis of urine. Until this condition is fulfilled, the majority of practitioners will not derive from the instrument more than a very small part of the information which it is calculated to afford.

Passing from the surface of the nerve itself to the immediate circumneural zone, the only differences seen between different healthy eyes are such as depend upon different degrees of tenuity and transparency of the retinal tissue, or upon differences in the colour of the background which shines through it. Speaking generally, the colour of the choroidal background ranges from a bright red in very light eyes, through an orange-red in those of somewhat darker tint, to an almost chocolate-brown in the dark races; and the connective tissue of the retinal fibre layer is distinctly coarser, and more streaked by manifest white fibres, in dark eyes than in light ones. It is very necessary to remember these differences in any estimate which is formed of the colour of the nerve surface itself, because all colour effects are liable to be more or less modified by the colour of the immediate surroundings; and hence in a very dark eye the roseate tint of the actual nerve structure is less evident than in a fair one. In the latter, again, the retina, even in that thickest portion of it which immediately surrounds the nerve, partly from its comparatively delicate texture, and partly from the penetrating effect of the bright colour behind it, will be practically invisible, and will allow not only the bright colour aforesaid, but also something of the finely granular appearance of the choroid, to show through. In very dark eyes, on the other hand, the circumneural zone of retina is distinctly visible as an opalescent film in front of the choroid, a film which has been compared to a layer of wet tissue paper, and which gradually fades away towards the periphery, until its presence is no longer discernible. Between these two conditions there is every possible gradation; and nothing but repeated observation can confer the power of readily distinguishing, in relation to the visibility of the circumneural zone of retina, between appearances which are physiological and those which are morbid.

Beyond the immediate circumneural zone, or, in very light young eyes, even up to the margin of the disc, the background of the eye presents a generally uniform aspect. The vessels of the retina ramify in an arborescent manner, the branches becoming smaller as they approach the periphery, and losing the central white line as soon as they fall below a certain magnitude. At about two diameters on the temporal side of the optic disc there is a space upon which vessels do not encroach; and the centre of this space is the fovea centralis, with its surrounding yellow spot; structures which, in moderately light eyes, present to the ophthalmoscope chiefly negative characteristics. The yellow spot is the thinnest part of the retina, and it therefore permits the colour of the subjacent choroid to show through a little more deeply than elsewhere. In dark eyes, the fovea centralis may be visible as a yellowish-white spot. In all other parts the details of the choroid are concealed by the interposition of the retinal layer of pigmented pavement epithelium, the structure of which is too fine to be seen by any enlargement which the ophthalmoscope can afford, but which presents a minutely granular aspect, difficult to describe in words. Over this finely granular surface, of some tint of yellowish or orange red or reddish-brown, the retinal vessels ramify, and upon it they are always rendered distinct by their difference of colouring. In many eyes the yellow spot is surrounded by a faint greyish halo at a distance of about a disc diameter; this shifts its position slightly with that of the mirror, and is probably due to the light being reflected from the edge of the slight depression in which the yellow spot lies.

In some very fair eyes, and especially in the very fair eyes of children, the layer of pavement epithelium is so deficient in pigment as to be transparent, and to permit the choroid to be visible. In such cases the deficiency of pigment usually extends to the choroidal stroma, so that through and behind the retina the choroidal vessels are clearly seen, and even the white background afforded by the sclera may be visible between the meshes of their network. In such cases, therefore, the arborescent vessels of the retina lie in front of another visible series quite differently arranged, being much more uniform in size, and arranged in lines which are approximately parallel. In cases of congenital deficiency of pigment, the interspaces between the approximately parallel vessels will be white; but if the pigment of the pavement epithelium has been removed by any failure of nutrition, while that of the choroidal stroma remains, the interspaces will be filled by the latter, and will be of some shade of chocolate-brown. Loss of the epithelium pigment occurs after middle life in many conditions, all of which are probably degenerative, but which scarcely amount to disease; and such loss reveals itself by the visibility of a more or less striped or variegated background to the retinal vessels, in place of the uniform and finely granulated background which has been described.

An appearance which is quite physiological, but which might easily be mistaken by a beginner for a pathological condition, is that known as the "shot-silk" appearance, a term that is as expressive as any more elaborate description. It is frequently present in young subjects, and depends upon some of the light being reflected from the surface of the retina, instead of penetrating its superficial layers.

It is necessary for the observer to be acquainted with the nature of two abnormal formations which are sometimes met with, and which, although they are usually associated with some imperfection of the eye in which they occur, do not constitute disease. They are: persistence of the hyaloid vessels or of some portion of their sheath, and the passage into the eye through the lamina cribrosa of the sheaths of some of the fibres of the optic nerve. As already mentioned on page 259, the dwindling of the hyaloid vessels may not be complete; and although I have never seen them in the adult extend so far forwards as to reach the lens, yet they may project some distance into the vitreous, and may be pervious to blood, the artery and veins in such cases being often twisted around each other in an intricate manner. In other cases the disappearance of the actual vessels may be complete, or nearly so, but a portion of their original sheath may remain, having the appearance of a delicate flocculus in the vitreous. I have seen one case in which the remains of the sheath, being rather coarse and conspicuous, were mistaken for a cysticercus; and another in which, being very faint and delicate, they were mistaken for a pathological flocculus in the vitreous, and were thought to justify a course of somewhat active treatment.

An object which advances forwards from the optic disc towards the observer can only be dimly seen when the disc itself is in focus, and requires the presence of a convex lens behind the mirror in order to bring its anterior portions clearly into view. The observer should first obtain a clear view of the disc itself, and of the point of origin of the object, and then, turning on convex lenses in succession, should trace the latter forwards until he obtains perfect definition of its apex or anterior extremity. Such an examination will usually leave no doubt as to its nature; and the actual extent of its projection forwards may be roughly estimated by the scale already given, by which a dioptre of refraction is equivalent to one-third of a millimetre of position. Remnants of the hyaloid vessels are generally discovered accidentally; and, as they occupy a position along a line extending from the disc towards the posterior pole of the lens, they scarcely ever fall into the axis of vision, and are not sources of inconvenience.

In certain eyes some of the fibres of the optic nerve carry their sheaths into the retina, usually only for a short distance. The portion of retina so affected is opaque, white and glistening, is continuous with the nerve surface, and thins off at its outer boundary, where it usually terminates in a sort of brush of fibres. Any vessels which pass through the opaque portion are concealed from view until they emerge from beneath it, and the margin of the disc is concealed in like manner. I have only once seen the whole circumference affected, and the formation is generally confined to a single patch, or to two patches, of variable position and magnitude. Sight is not necessarily impaired; but in the case mentioned, in which the fibre sheaths entered the eye all round the nerve, there was a very high degree of hypermetropia and very defective vision, with associated convergent strabismus.

The formation described is the rule in the eyes of rabbits, in which two bundles of sheaths enter the retina in a horizontal direction. The appearance is exceedingly characteristic, and could scarcely be mistaken, even by the least experienced observer.

In describing the diseases of the parts which enter into the formation of the background of the eye, the most convenient order to follow will be to commence with the optic nerve and retina, and to proceed to the choroid and sclera.

Like other nerves, the optic nerve is liable to inflammation, presumably confined to its connective tissue elements, but capable of giving rise to effusions by which, or by their eventual contraction, the fibres themselves may be injuriously or fatally compressed. It is also liable to be compressed by effusions within its sheath, but external to the trunk itself, effusions which are generally symptomatic of some intracranial affection, and often of some intracranial tumour. Either of the foregoing forms of disease may be recovered from, or may terminate in complete atrophy; and the nerve is also liable to a form of atrophy which is probably analogous to the sclerosis which affects other portions of the nervous system, and in which the atrophy is said to be primary. Mention has already been made of the proneness of the nerve to yield to the increased intra-ocular pressure of glaucoma, so that it is to some extent pushed backwards out of the eye; and in very chronic cases, which are not complicated by intercurrent inflammation of neighbouring tissues, atrophy may also be produced by this form of compression. Furthermore, it may occur as a consequence of poisoning by lead, and perhaps by other agents, such as tobacco and alcohol, or as a result of general nervous exhaustion.

The most common form of affection of the optic nerve is frequently described as "optic neuritis," or by exceptionally bad writers as "papillitis," the entrance of the optic nerve having been called a "papilla," presumably because it bears no resemblance to one. The use of either term appears to me to be misleading, and I prefer to speak of the condition as "choked disc." By doing so I avoid giving a possibly unsound explanation, and simply describe a condition which certainly exists.

Choked disc.—The appearances of choked disc are primarily those of swelling of the intra-ocular termination of the optic nerve, with œdema of the swollen tissues, and obstruction to the flow of blood through the vessels. The first link in the chain of morbid action is probably obstruction to the outflow of blood through the retinal vein, œdematous swelling following as an immediate consequence. The swelling is not limited to the mere surface of the disc, but extends over a larger or smaller circumneural zone of retina, and the portion thus affected is necessarily of impaired transparency, and so conceals the disc margin from view. The vein which is obstructed becomes winding and varicose, a condition which gradually spreads back from the point of obstruction towards the branches; and as the swelling of the optic nerve increases, and advances farther into the cavity of the eye, the vessels are lifted with it and pushed forward in bold curves. The general result is that the optic disc, as such, can only be recognised as the place of meeting of the vessels, and that it presents the aspect of a whitish or semi-opaque projection of indefinite outline, in which distended vessels are visible as they approach its surface, and become concealed as they sink into its deeper parts. The amount of actual swelling can be measured by the ophthalmoscope, the observer taking the most prominent vessel as his test object, and ascertaining the power of the convex lens which affords in the erect image the most perfect definition of it.

In a great many of such cases the obstruction which produces the swelling is probably due to effusion within the sheath of the optic nerve, effusion by which the trunk is compressed and the channel of the emergent vein diminished in calibre. Such effusion unquestionably occurs in some cases of intracranial meningitis; and it is at least possible that in some intracranial maladies which are not primarily of an inflammatory character, such as tumours, there may be a mechanical cause for the passage of an increased amount of cerebro-spinal fluid into the sheath, and that the symptoms of obstruction may be thus produced without inflammation, and simply by mechanical means. It is at least certain that the sheath has been found distended in post-mortem examination, the distension being most manifest in the immediate vicinity of the eye.

The parts chiefly affected in the condition described are the vascular and connective tissue elements of the nerve disc and of the circumneural zone, and these have only an indirect relation to the function of vision. In the region of the macula lutea there are neither vessels nor connective tissue, so that the retina retains its transparency, and retains also its power of receiving and transmitting images. Hence, although the swelling and obstruction in and around the disc may be considerable, yet, so long as they are not sufficient to arrest conduction through the nerve fibres, there is no reason why sight should be impaired. It is a matter of daily observation that we meet with choked disc in cases in which there is no impairment of sight; and such impairment does not commence until either conduction is arrested, possibly by increased pressure consequent upon direct increase in the amount of effusion, possibly by the contraction around the trunk of the effused material, possibly by secondary changes, such as hæmorrhage or inflammation from mechanical disturbance, in the tissues of the retina. It is certain that a very large amount of disc swelling may occur and may be recovered from, sight never suffering in any appreciable degree. It is highly probable that the area of the blind spot corresponding with the nerve entrance would in such cases be extended, but it is rare for the condition of the patient to allow this point to be satisfactorily determined.

Choked disc is more frequently discovered by the physician than by the ophthalmic surgeon. In a large proportion of cases it is associated with grave intracranial lesion, very frequently with tumour in some portion of the brain. The tumour may be either a gumma, or it may be malignant or tuberculous; and the diagnosis can only be arrived at by considerations independent of the state of the disc, which cannot do more than establish the probability of some serious mischief. In the great majority of cases both eyes are affected, either simultaneously or one very soon after the other; and the causes of monocular choked disc are exceedingly obscure.

The treatment of choked disc is primarily that of the lesion from which it appears to spring. So long as sight is unimpaired no other consideration need interpose, and in the majority of cases recourse will be had to iodides and to mercury. Under their use intracranial gumma may wholly disappear, and with it the disc affection also. Perhaps the only condition in which such treatment would be definitely contra-indicated would be when there was manifest cancer in some other organ, with a probability of secondary deposit in the brain; but every case must be carefully considered on its merits. Under the use of inunction and iodide of sodium I have seen complete recovery from choked discs, and from such associated symptoms as intense headache, and paresis of both external recti, in patients in whom no suspicion of syphilis could be reasonably entertained, as well as in others in which a specific history was declared; and whenever there is any ground for hope that the primary lesion may admit of removal by absorption, the medicines most likely to promote such a result should be perseveringly administered. It is unnecessary to say that the prognosis must always be very doubtful, and that it must remain so for some time after apparent recovery.

In many instances of choked disc, after the lapse of a certain time, the sight will begin to suffer. In former years, when the ophthalmoscope was little used by physicians, the impairment of sight was frequently the first thing which seemed to call for an examination of the eye; and it was then not uncommon for atrophic changes to be far advanced. The beginning of the affection had been entirely lost sight of, and only its later stages were observed. These later stages were referred to various hypothetical conditions (in many instances to the excessive use of tobacco), and the nerve atrophy in which they usually terminated was described as a disease, with no reference to, and frequently with no suspicion of, the swelling by which it had been preceded. Such a history is now comparatively rare, and the condition of the discs will in most cases be ascertained before vision is affected. As soon as it begins to suffer, however, the problems presented by the previous symptoms become seriously complicated. The decay of sight may be due to such an increase of the quantity of fluid within the nerve sheath as suffices entirely to arrest conduction, or to the contraction of plastic matters in the connective tissue between the fibres, or to inflammatory or degenerative changes in the nerve or retina, or to passive hæmorrhages in the swollen and congested parts. Upon the probabilities in each of these states the ophthalmoscope will throw much light. If there be merely an increase of fluid within the nerve sheath, the swelling of the disc will be sustained or even increased, but the colour of the swelling will be unchanged. If there be contraction of previous effusion, the appearances will be those of commencing atrophy; that is, the swelling will be diminished, and either over its whole surface or in parts it will be pale, from the arrest of circulation in the capillaries and arterioles. The presence or absence of hæmorrhages may be determined by simple inspection; and degenerative changes which affect the sight commonly show themselves in white patches, probably of fatty degeneration, which occupy the retina in the neighbourhood of the yellow spot, a part which is probably rendered vulnerable by the scarcity or absence of large vessels.

When sight begins to fail, in a case in which mercury and iodides have been administered from the beginning, there is scarcely a hope of its being preserved by any kind of medicine. If, on the other hand, we find a choked disc passing into atrophy, in a case which has not been mercurialised, the issue is more hopeful. I have lately published in the Transactions of the Clinical Society * the history of a gentleman who had severe malarious fever, complicated by meningitis, in a West Indian island, and who came to this country practically deprived of sight. His discs were white from capillary anæmia, and evidence of antecedent swelling was furnished by a sign which seldom misleads, namely, by the fact that the vessels, where they crossed the margin of the discs, were lifted forwards in bold curves, while the veins were

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tortuous for a considerable distance. There could be little doubt that the effusion of meningitis had extended into the nerve sheaths, that the discs had been choked and swollen, and that the effused fluid was undergoing contraction and gradually strangling the life out of the fibres. The obvious indications were to do all that was possible to promote the absorption of effused material, and to sustain the nutrition of the nerve fibres. Mercury and iodide of potassium were administered by the mouth in suitable doses, and strychnia was given hypodermically. After about a month definite improvement had occurred, and in about nine months the recovery of sight was complete, and has since proved to be permanent.

When, however, the full effect of mercury and of iodides has already been produced, and when, notwithstanding their influence, a patient with choked discs begins to exhibit evidence of failing sight, little hope of preserving it by medicine can be entertained. In such circumstances I have lately determined to try the effect of a mechanical remedy, and to open the nerve sheath in the hope of giving exit to the contained fluid. The suggestion that this might be done was first made by Dr. de Wecker in a paper which he read before the International Ophthalmological Congress, held in London in 1872, and in that paper he spoke of having operated in two cases, in both of which atrophy was too far advanced for any great benefit to be derived. He did not expose the nerve, but only felt for it, and endeavoured to incise the sheath by means of a guarded knife. Soon afterwards Mr. Power repeated the endeavour, using an unguarded knife, and I doubt whether the operation, thus performed, would not be extremely uncertain in its character and effects. It would be hardly possible to be certain whether the sheath had been adequately incised, and difficult to avoid doing unintended injury, either to the optic nerve itself or to other structures. In a patient at the National Hospital, in whom there was great and increasing swelling of one optic disc, with loss of vision over the temporal half of the field of the affected eye, I divided the external rectus muscle, first inserting sutures, by which the two portions could be rapidly and securely united. The eye was then rolled inwards by an assistant, Tenon's capsule and other resisting structures being carefully divided by scissor snips, until the place of insertion of the nerve came into view. A hook was then passed round the trunk to isolate and steady it, the sheath was fixed by a sharp hook and carefully divided along the axis of the nerve. A small quantity of opalescent fluid escaped, showing that the operation had been effectual, and the sutures were then tied and the lids closed. No reaction followed, and the patient was at once relieved from a headache which had for some time been troublesome. After five days the sutures were removed, the divided muscle was firmly reunited, and a glance with the ophthalmoscope showed a marked diminution of disc swelling. This diminution was afterwards steadily progressive, and the outlines and vessels were clear in every direction in about a month after the operation. There has been no increase of the extent of field, but the central vision remains normal. The operation has done no more than demonstrate the practicability of opening the nerve sheath with certainty and without injury, and of evacuating the contained fluid; but further experience must be obtained before it will be possible to speak other than conjecturally with regard to the probable usefulness of the proceeding. I am inclined to think, however, that it will afford much security against blindness consecutive to distension of the sheath, in cases in which this distension occurs as a complication of meningitis, or as a complication of any intracranial growth which is not so situated as to intercept the conduction of visual impressions. A full report of the case will be found in *Brain* for July, 1887. Since the publication of the first edition I have performed the same operation in three other cases with marked benefit, amounting in two of them to restoration of vision from actual or immediately impending blindness. A full report of these cases was read before the Glasgow meeting of the British Medical Association in 1888, and was published in the Journal.

I have referred to the opinion that the condition of "choked disc" may always be called "optic neuritis," and this opinion mainly rests, I believe, upon the presence of leucocytes in the swelling. I regard the state of choked disc as primarily one of œdema, in which inflammatory conditions are liable to arise as consequences of the distension and disturbance of tissue caused by the effusion of blood and serum. When "neuritis" occurs in the extremity of a choked optic nerve, I look upon it as analogous to the erythema of a dropsical leg, and as differing from true neuritis as much as that erythema differs from inflammation of the leg. Every one who has drained away fluid from a dropsical leg has seen the plastic character of the effusion, and a similar effusion in the optic nerve would be sufficiently contractile to injure the fibres by its shrinkage, without any need of inflammation to explain such an event. To rely upon the presence of leucocytes as a proof of inflammation, and to assume that the inflammation was a primary element in the condition, appears to me to involve undue forgetfulness of broad clinical distinctions.

Neuritis.—In what I regard as actual or primary neuritis the changes in the disc are much less conspicuous than in the cases last described. Neuritis usually commences in the trunk of the nerve, behind the eyeball, and descends into the eye. Even in its earliest stages it affects vision in a serious degree, often before any signs of it have reached the disc; so that it may be looked for before any certain indications of its existence can be discovered. The symptom most significant of neuritis is diminution or loss of vision over the central part of the field, the patient saying that he sees a dark spot or cloud in front of him. When vision is accurately tested, it is found to be much diminished in acuteness over the central region, the lateral vision being little or not at all affected, as if the fibres chiefly involved were those proceeding from the region of the yellow spot. In the majority of cases only one eye is at first affected, and the earliest changes in the optic disc will often be so slight that only a skilled observer, using the best attainable illumination and the highest magnifying power, could be certain of their presence. They would constantly escape observation in the inverted image when they are manifest in the erect. A little increase of the ordinary capillary flushing, a slight veiling of the outlines of vessels or of the nerve margin by effusion; these are symptoms to which, when they are attended by central deficiency of sight (central "scotoma," as it is called by many writers), very grave significance must be attached. In some cases a cure may be effected, but in many the conditions described pass into complete nerve atrophy, attended by hopeless blindness as far as objects are concerned. The loss of perception of light is seldom complete.

Of the causes or pathology of this form of neuritis, as, indeed, of other forms, little that is definite has yet been ascertained. When the presence of optic neuritis is recognised, the patient should from the first be warned of the serious character of the affection. Due weight should be given to all diathetic considerations which may seem to have any bearing upon the case, and too much care cannot be taken in the investigation of every point which may assist the surgeon. It is maintained by some writers that exposure of the temporal region to cold is both a cause of the disease and a condition to be sedulously guarded against during its existence; but on these points I have no direct evidence to adduce. The remedies to which I attach most importance are the local abstraction of blood and the internal administration of mercury. The bleeding is best accomplished by some one of the various forms of artificial leech, by which three or four ounces of blood may be quickly drawn from the temple, and when this has been done the eyes should be entirely secluded from light for forty-eight hours. The plan most generally convenient is to take the blood in the evening, the patient being in bed. His bedroom should then be completely darkened, and should be kept dark all the next day, a small nightlight being used in order that he may be fed and otherwise waited upon. On the second morning after the bleeding a moderate amount of light may be admitted, and the patient may be allowed to get up; but for some time the eyes should be protected against glare by dark blue goggles or glasses. The mercury may be given in the form of perchloride, say a sixteenth of a grain three times a day for an adult; but if any diathetic considerations intervene (if, for example, the urine be loaded with lithates, and some other medicine may for a time be indicated), mercurial inunction may be commenced in order that no time may be lost. It must not be supposed that the cure of a case of neuritis by mercury affords any evidence that the malady was of syphilitic origin. It was first pointed out by the late Dr. Anstie, and is, I believe, indisputably true, that mercury exerts a special influence over the inflammations of all the structures which are supplied by the fifth nerve.

The progress of neuritis is better tested by the vision than by the ophthalmoscope. The perimeter should be used from the first, so that a plan of the area of defective vision may be preserved for reference, and the central and lateral acuteness should be noted. If the area of the defect extends, and if the acuteness of vision over this area declines, the worst result must be expected, and definite signs of nerve atrophy may usually be looked for. After mercury has been given without effect, the resources of treatment are not extensive, and the best hope is afforded by strychnia, which for this purpose is, I think, best given by hypodermic injection. I commence with a sixtieth of a grain of the sulphate, and increase this amount cautiously, until twitching or other general symptoms are produced. It is well to bear in mind the already-mentioned hypothesis about surface cold, and to protect the patient against being injured in this way. In favourable cases improvement soon becomes manifest after bleeding and mercury. The patient states that the central cloud is smaller and less dense, and his statements are confirmed by accurate testing. The mercury should be cautiously continued until recovery is complete, the doses being so regulated as just to maintain its influence. The return to the use of the eyes and to other freedoms of health should be very discreetly managed. Since I have gained the experience of incision of the nerve sheath, which is mentioned on page 313, I should advise the performance of this operation in any case of neuritis which did not rapidly improve under treatment. To relieve the nerve trunk from constriction by its sheath would be likely, I think, to promote the occurrence of resolution.

I have seen many cases of neuritis which recovered under treatment, and in which the affection remained monocular, the second eye never participating. In the cases which lead to atrophy, on the contrary, the second eye as a rule becomes affected shortly after its fellow, and blindness of both is a not uncommon result. I am acquainted with a family in which no less than five members have lost vision in this way; all of them in other respects being strong and apparently healthy people.

Atrophy.—The form of atrophy which is called simple or sclerosal is often typically displayed as one of the symptoms of locomotor ataxy; and it may even be the first ataxic symptom which attracts notice. There will be general impairment of vision and often of colour sense, with pallor of the optic discs and no swelling or effusion in them. In the presence of such symptoms the tendon reflexes of the knees should be carefully tested, and lightning pains should be inquired for. If these are present (the patient will often say that he is subject to flying rheumatism), or if the knee jerk be decidedly defective on one or on both sides, the diagnosis of ataxy may be made with a near approach to certainty. Cases of this description always terminate in loss of sight, but even years may elapse before the blindness is complete. Attention to the general health, and the careful administration of strychnia may be said to comprise all that can be done for them.

The effect upon the optic nerve of the increased intra-ocular pressure of glaucoma has already been mentioned in the chapter on that affection, and need not be again described here.

The ophthalmic surgeon will frequently be consulted about cases in which atrophy of the optic nerve has already made some progress, and in these, by comparing the history with the ophthalmoscopic appearances, he will generally be able, without affect injuriously the nutrition of the whole membrane. Hence the retina may undergo atrophy coincidently with the optic nerve; and, even before atrophy is established, will frequently present patches or spots of yellowish-white deposit, which are probably areas of fatty degeneration. The absence of connective tissue in the region of the yellow spot confers a comparative immunity from such changes upon the centre of vision, and when existing elsewhere they do not of necessity interfere in any great degree with useful sight.

Embolism.—Arrest of the retinal circulation by embolism is probably only met with in persons who are suffering from deposits on the aortic or mitral valves, and who therefore have in most instances been the subjects of acute rheumatism with cardiac complications. The plugging of the central artery by an embolus is immediately destructive of even perception of light, but in a few cases such plugging has occurred in one of the branches of the artery, and has left the sight of one part of the visual field comparatively uninjured, while that of other parts has been at once extinguished. The impaction of an embolus may occur during either sleeping or waking, the patient in the latter case being able to state the moment of loss of sight, while in the former he can only say that he awoke with a blind eye. The history of such a sudden invasion points almost conclusively to either embolism or intraocular hæmorrhage, and of the two conditions embolism is more common in the young, and bleeding in the middle-aged or old. Any doubt may be immediately set at rest by the ophthalmoscope, the appearances in either case being unmistakable. Within a short time of the impaction of an embolus, the connective tissue of the retina becomes white and turbid, so as to conceal the colour of the choroid, save only in the region of the yellow spot, where, the connective tissue being absent, the colour still shines through. The general effect, therefore, is to produce a white background, in which there is a vivid red spot (the macula) contrasting strongly with its surroundings. The position of the optic disc may be discovered as the place of meeting of the veins, which will be more or less veiled by turbid connective tissue, and in which the blood is often broken up into small separate columns, which move irregularly to and fro. The arteries are empty, and can be traced with difficulty as white lines. After a short time, varying from a week to a fortnight, the retina recovers its transparency, so that the white background and the red spot are no longer visible; but the optic nerve speedily passes into complete atrophy, and the arteries remain empty and consequently inconspicuous. The condition is in most instances hopeless from the first, there being no collateral channels through which the circulation of the retina can be maintained, and the affection scarcely possesses any other interest than that of a pathological curiosity. There have, however, been examples of partial recovery with a blind area, probably due to the timely passing on of the plug from the main artery to one of its branches.

Retinal hæmorrhage.—Hæmorrhages into the vitreous chamber have already been described at page 265; and those which occur in the retina may be either arterial or venous, the former being most common in persons in whom the arterial degeneration of advancing life has commenced, the latter in women during the irregular congestions incidental to the impending arrest of menstruation. Arterial hæmorrhages also occur in the course of the degenerative changes associated with albuminuria or with diabetes, and they form a distinguishing feature of the least tractable forms of glaucoma.

The effect upon vision of a retinal hæmorrhage will depend almost entirely upon its magnitude and its position, and it may occasion anything, from slight defect to total blindness. As a rule, however, the impairment, whatever its extent, presents the characteristic sign of suddenness of invasion.

A retinal hæmorrhage is always readily recognisable as a patch of effused blood by the ophthalmoscope, but this general character is modified by the precise position which the effusion occupies. If the ruptured vessel is of large size, and lying immediately underneath the limiting membrane, the blood may pass between this membrane and the fibre layer, and may be spread out in an uniform patch with sharply defined edges, and of size determined by the amount of the bleeding. If the ruptured vessel is smaller and to some extent buried in the connective tissue of the fibre layer, the effused blood will split up the fibres and pass between and among them, presenting delicate striations upon its own surface, and assuming shapes which are governed by the resistance it encounters. The interpenetration of the fibre layer by the blood occasions the patches to terminate in a sort of brush-like extremities, or to assume something of the shape of a candle flame, and the expression "flame-shaped hæmorrhages" is frequently employed by writers. The hæmorrhages of old people, occasioned by the giving way of a degenerated arteriole, are often individually very small, and are sprinkled in tiny dots over a limited area; and these owe their chief importance to the indications they afford of what is likely to occur elsewhere.

In the retina, as in other tissues, effused blood is soon removed by absorption; and the amount of permanent mischief inflicted by a hæmorrhage will depend mainly upon the extent to which the blood has lacerated or injured the delicate structures into which it has been poured out. From this point of view, the least important bleedings are those in which the blood lies in an uniform patch beneath the limiting membrane, and this occurrence, according to my own observation, is almost peculiar to the climacteric venous hæmorrhages of women. There may be almost complete loss of sight for a time, depending on the absolute opacity of the blood layer; but when this blood layer has disappeared, very little impairment of sight may be left behind. In flame-shaped hæmorrhages, on the other hand, by which the fibre layer is torn and otherwise injured, and by which the fibres are compressed and irritated, any important degree of restoration of vision is comparatively rare.

The treatment of retinal hæmorrhage must be conducted upon general principles. When it occurs in an elderly person with hard arteries, it is to be looked upon as a warning that the next blood-vessel which gives way may probably be in the brain, and the patient should be cautioned to avoid all acts and things by which such a catastrophe could be accelerated. He should not hurry to a train, nor, indeed, should he hurry at all. He should drink only moderately of fluids, either alcoholic or non-alcoholic, and should avoid any sudden bodily exertion, cultivating deliberateness as a primary condition of safety. It is possible that iodide of potassium in small doses might promote absorption, but the question whether it should be given would depend upon the fitness of the patient for such treatment.

In the hæmorrhages of the climacteric period the use of iodide and bromide of potassium has often appeared to me to be distinctly serviceable, and I have met with examples of complete restoration of vision when these medicines have been employed. In most instances, however, the persistence of some degree of defect must be expected.

In flame-shaped hæmorrhages, especially when, as often happens, they are multiple, and still more when they affect both eyes, the outlook is very serious.

They mostly occur in patients past the middle period of life, with congested and torpid livers, or in younger persons of hæmorrhagic diathesis; and the surgeon will generally find ample scope for treatment in the rectification of conditions which are manifestly amiss. When no other indications remain, it is sometimes possible to promote the absorption of the effused blood by pilocarpine diaphoresis; and it is always necessary, in all forms of retinal hæmorrhage, to maintain free action of the bowels. Not only is the avoidance of straining important, but moderate purgation will be likely to promote absorption in a marked degree.

Retinitis.—The most common form of inflammation of the retina is that which is frequently associated with renal degeneration, insomuch that it is often described as "albuminuric retinitis." It does not appear, however, to depend upon the albuminuria, but rather to be an effect of the existence in the arterioles of the retina of changes of the same character as those which lead to albuminuria when they exist in the arterioles of the kidney. It is certain that the retinal and the renal changes stand in no discoverable relation to each other, except that they are frequently found in the same person; insomuch that certain appearances in the retina at once demand an examination of the urine, and any impairment of sight in an albuminuric subject at once excites suspicion of the presence of this form of retinitis. In some instances the retinal symptoms precede the renal, in others they succeed them. The retinal appearances are chiefly that the transparency of the membrane is diminished, and the visibility of the choroidal colour damped, by irregular patches of a whitish or opalescent character, among which round or oval yellowish-white spots are deposited, the latter being not unfrequently grouped in a sort of stellate pattern around the yellow spot.

Among the irregular white patches there are frequently small effusions of blood; and the optic nerve sometimes participates in the general disturbance, and has its surface and outlines blurred by effusion. There is nothing absolutely pathognomonic in the changes, but they are as a rule characteristic; and albuminuria will, in the enormous majority of cases, be found associated with them. The treatment of the retinal is purely that of the renal affection, and the result will much depend upon the gravity of the latter. If this can be arrested or cured, the vision will probably be preserved, even if in somewhat diminished acuteness; and if the kidney disease tend to a fatal issue, the patient seldom becomes blind before death terminates his sufferings. As a general rule, it is permissible to use the eyes over any occupation or amusement which can be undertaken, and the condition of the retinæ may be regarded as being entirely subordinate to that of the general health.

A form of retinitis is met with in diabetes, which presents appearances not essentially differing from those of the albuminuric form, and, like albuminuric retinitis, requiring no other treatment than that of the systemic malady. The lesson to be learnt from both forms is chiefly that every manifest retinal disturbance should lead to careful urinary examination. Diabetes is so often associated with cataract that the state of the retina in diabetic patients should always be scrutinised with as much care as circumstances will allow, lest anticipations of benefit, from the removal of an opaque lens, should be disappointed on account of the co-existence of retinal trouble.

The remaining form of diathetic retinitis is the syphilitic, which is characterised, as far as ophthalmoscopic appearances go, by the presence of filmy white turbidity diffused in irregular patches over the membrane. Not only these patches, but also the background of the eye generally, is apt to be veiled by a very slight cloudiness of the layer of vitreous immediately in front of the retina, a state as if it were beset by fine dust, which has been described by De Wecker as pathognomonic of syphilis. The syphilitic form of retinitis is usually met with at a somewhat advanced stage of the constitutional disease, and in patients in whom the earliest stage has been inadequately treated. Frequently there has been a chancre some years previously, for which mercury has been given for a few weeks; and there may have been some secondary eruptions, usually described as being of trifling severity and soon got rid of. Then a long period of apparent health has intervened, interrupted at last by some depressing agency, after which the affection of the sight has declared itself. The degree of impairment will depend in great measure upon the density and extent of the retinal opacities, and still more upon whether the choroid participates in the disease.

In any case of syphilitic retinitis, if the optic nerve is distinctly hyperæmic, and especially if the outer tunics of the eye show signs of congestion, depletion by an artificial leech is to be recommended, and very strict disuse of the eyes should be enjoined. If there be any increase of tension, physostigmine must be employed, followed, if necessary, by sclerotomy or iridectomy. All manifestly injurious influences, such as extreme cold, strong light, exposure to irritating vapours, should be scrupulously avoided.

When all this has been done, it remains to treat the syphilis; and the experience of many years convinces me that this can be done only in one way. Syphilis may be cured, at least, in any patient under forty or fifty years of age, by the steady administration of mercury for a twelvemonth or more, this administration being so guarded and controlled as never to develop the poisonous effects of the medicine. When syphilis has not been thus treated, and when its late forms show themselves at all sorts of unexpected times, the best remedy for any local symptom of pressing importance is iodide of potassium, given in the largest doses which can be borne, and continued until improvement under its use ceases, or until the patient appears to be well. The local symptom, be it a syphilitic retinitis, a gumma in the brain, or what not, may in this way be cured; but nothing will have been done for the removal of the constitutional taint, and the patient will be just as liable to another syphilitic outbreak as he was before. In order to cure the constitutional taint, recourse must be had to mercury, and the time over which its use should be extended must be proportionate to the prematurity of its previous abandonment. It is often well to begin with a course of inunction, or of mercurial vapour baths, and to continue by the steady administration of the perchloride in small doses. It is often quite curious to observe the extent to which a patient, under this treatment, will gain flesh, and will develop the conditions of robust health.

There is yet another form of retinitis, the pigmentary, in which the choroid always participates, and which therefore forms a fitting link between the diseases of the two membranes.

Pigmentary retinitis is an exceedingly chronic disease, which usually commences early in adult life, or sometimes in childhood, and which is attended by symptoms not to be mistaken. These are: night blindness and gradual contraction of the field of vision. When these conditions co-exist, and there is no increase of tension, the ophthalmoscope will reveal in the very earliest stages, stellate pigment spots, resembling bone corpuscles as seen under the microscope in the neighbourhood of the equator. Later there is seen a curious irregular black striation of the background of the eye, seldom approaching very close to the optic nerve, but extending in the direction of the periphery. The striation is of such an aspect that it received the name, in the first days of ophthalmoscopic investigation, of "tiger-striped," the black marks being more abundant in some eyes than in others. They are produced by deposits of pigment upon and around the retinal vessels, and by isolated patches running into the intervascular spaces; and the position of these patches in the retina itself is shown by the fact that they bury and conceal small vessels. The surface of the optic nerve presents a peculiar character of whiteness from capillary anæmia, and the central vessels are usually of small calibre. The pigment of the pavement epithelium of the deepest retinal layer is usually removed, so that the structure of the choroid and the nearly parallel direction of its vessels, with the intervals between them occupied by stroma pigment, can be seen over large areas; but there will be no atrophy of the choroid, and hence no white patches in which the sclera is exposed. The contraction of the field of vision is usually concentric, and may be so extreme that a patient who is able to take in at a view, and to read without difficulty, one word of the smallest type, might yet be wholly unable to see any of the boundaries of even a small page, or to guide himself in safety through the streets. With the loss of daylight the central vision becomes much impaired, and patients will usually complain, first, that they cannot see at all by twilight; and next, that in daylight they seem to be looking through a tube; thus giving a forcible illustration of the effect of the contraction of the field. These symptoms are, of course, a question of degree. At the beginning, or perhaps even when night blindness is first complained of, the contraction of the field may require the perimeter for its establishment; and the ordinary course of the disease is that it drags on slowly, an interval of perhaps twenty years elapsing between its discovery and its termination in blindness.

The pathology of pigmentary retinitis is that it is a chronic inflammation and degeneration which affects the adjacent surfaces of the retina and of the choroid, involving the chorio-capillaris, the pavement epithelium and the percipient layer, and which, as it proceeds, unites these textures together and involves them in one common ruin. It usually commences in a zone near the equator, and spreads slowly from the inner margin of this zone towards the centre, destroying vision as it goes. It does not affect the conducting fibres, which are in a layer anterior to it; whence it happens that objects may sometimes be seen when they are beyond the zone of the disease, as well as when they are within it. In other words, both the extreme outer circle and the central part of the field of vision may be preserved, with a region of absolute blindness between the two.

It has been asserted that the subjects of pigmentary retinitis are, in nearly half the cases of its occurrence, the offspring of marriages of consanguinity; but the statistics on which this statement was based were probably obtained in a population among whom marriages of consanguinity were very common, and the facts are certainly otherwise in England. I have found, however, that the disease generally occurs in more than one child of the same parents; and often, more or less, in all their children; and I make a point, whenever a case of pigmentary retinitis is brought to me, of asking to see other members of the family.

In a disease which naturally follows so slow a course it is very difficult to arrive at any certain conclusions about the efficacy of any form of treatment. The only medicine which has appeared to me to exert any influence has been iron, given continuously for long periods in small doses, and regarded as a food rather than as a medicine. Possibly it supplies to the blood something which is antagonistic to the influences on which the increase of the disease depends. However this may be, I have had patients under my observation for many years who have taken iron continuously, and in whom not only has the disease scarcely advanced, but who were themselves convinced of the importance of the treatment, and were sure that they lost ground after discontinuing it for a month or two. I have given various preparations, most frequently the tincture of the perchloride, and beyond this I have no suggestion to offer. It is worthy of note that any preparation of iron will sometimes disagree if given in the customary manner, almost immediately after food, its astringency possibly interfering with the secretion of the gastric juice. When this happens, the difficulty may be overcome by giving the dose about one hour before a meal or three hours afterwards. It is necessary to note that Mr. Marcus Gunn has observed some extension of the field of vision after the application of continuous galvanic currents, but the improvement so produced has been only temporary.

I have lately seen what might be called pigmentary retinitis of another character in a young man suffering from congenital amblyopia. His sight was almost too defective to admit of measurement, but he had been said to have nothing discoverable the matter with his eyes. Direct ophthalmoscopic examination showed that the whole of the region of the macula, in both eyes, was dotted by a very fine black stippling, looking like a sprinkling of fine black powder when seen under an enlargement of thirteen diameters, and apparently situated in the retina. The condition was wholly invisible when looked for with the inverted image.

Detachment of the retina is a condition in which some portion, or the whole, of the membrane is loosened from its attachment to the choroid, and elevated by the effusion of fluid underneath. Detachment may be traumatic, or it may be a result of what is vaguely called "subretinal dropsy," or it may be an early symptom of the growth of a tumour from the choroid. It has also been ascribed to the contraction of films formed within the vitreous body as results of certain forms of choroiditis. It is a not infrequent termination of cases of extreme myopia, in which the ocular tunics have been stretched to the point of yielding.

Detachment of the retina usually occurs suddenly, and it produces loss of vision on the corresponding (that is, the opposite) part of the field. If the upper part be detached, the patient will lose sight of the floor; if the lower, he will lose sight of things on a higher level than his eyes. If a detachment be small, the vision of the rest of the retina may not be very much affected; but if the detachment be large, the shock to the circulation of the whole membrane, and, therefore, to its functional activity, is generally very considerable.

In order to obtain a good view of the condition with the ophthalmoscope, it is often necessary to dilate the pupil; and, even when this is done, it often happens that nothing abnormal can be seen in the region generally first looked at, that of which the optic nerve is the centre. The patient must be directed to turn the eye right and left, upwards and downwards, and when the affected region comes opposite the pupil the detachment will be visible. When it is small, it may appear as a mere grey eminence rising from the background of the eye, and comparable to a blister on the skin; but as soon as it is at all extensive, the detached portion, on continuously for long periods in small doses, and regarded as a food rather than as a medicine. Possibly it supplies to the blood something which is antagonistic to the influences on which the increase of the disease depends. However this may be, I have had patients under my observation for many years who have taken iron continuously, and in whom not only has the disease scarcely advanced, but who were themselves convinced of the importance of the treatment, and were sure that they lost ground after discontinuing it for a month or two. I have given various preparations, most frequently the tincture of the perchloride, and beyond this I have no suggestion to offer. It is worthy of note that any preparation of iron will sometimes disagree if given in the customary manner, almost immediately after food, its astringency possibly interfering with the secretion of the gastric juice. When this happens, the difficulty may be overcome by giving the dose about one hour before a meal or three hours afterwards. It is necessary to note that Mr. Marcus Gunn has observed some extension of the field of vision after the application of continuous galvanic currents, but the improvement so produced has been only temporary.

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In cases of uncomplicated detachment, whether arising from injury or from hypersecretion of subretinal fluid, the eye will usually be found softer than normal. When detachment is an early symptom of the growth of an intra-ocular tumour, the tension will usually, although not always, be increased. The estimation of tension is therefore an element of the first importance in diagnosis.

The prognosis of detachment is very unfavourable, and an eye in which it has occurred may usually be regarded as being on the high road to destruction, even although some vision be still retained. The few exceptions have been furnished by cases in which the evacuation of the subretinal fluid has been followed by permanent restoration of the retina to its proper position, but this result, although it may often be aimed at, will seldom be secured. An advanced degree of myopia, or any grave constitutional disease to which the local malady may be due, or the presence of an intra-ocular tumour, would alike exclude reasonable expectation of improvement.

Assuming that none of these unfavourable conditions are existing, it will in most cases be desirable to operate, and with as little delay as possible. Time is of especial value when the detachment is at the upper portion of the retina, because in these circumstances it is likely to be daily rendered more extensive by gravitation, the weight of the subretinal fluid constantly tending to lift and detach more and more of the still adherent portion of the membrane. When the detachment affects the lower portion, this action is less likely to occur.

The patient should from the first be confined to bed, and kept in the most perfect attainable state of bodily repose, with limited supplies of fluid; and an attempt may be made to promote absorption of the effusion by pilocarpine diaphoresis. When an operation is determined upon, the eye being completely cocainised, and the position of the detachment accurately determined, the surgeon should divide the conjunctiva over this position with scissors, and dissect it up so as to leave a patch of sclera exposed. Through this patch a broad cutting needle should be thrust obliquely, and then slightly turned on its axis, so as to cause the puncture to gape. If the right spot has been chosen, an escape of yellow serosity will follow, upon which the needle may be withdrawn, and the wound dilated by a fine grooved director, with the object of giving exit to the whole of the fluid. If any, however small in quantity, be left behind, re-attachment of the retina is not likely to occur. The patient should immediately return to bed, with both eyes bandaged, and no examination of them should be made for some days. In favourable cases, when the bandage is removed, the field of vision of the affected eye will be partially or completely restored, and the ophthalmoscope will no longer display a detachment. Great caution must be exercised before any use of either eye can be sanctioned. In the majority of cases the conditions of sight and the position of the retina will be much what they were before the operation, and nothing more can then be attempted with any prospect of benefit. The detachment will usually become complete, the retina being adherent only at the ora serrata and at the insertion of the optic nerve, and the blindness must then be absolute. In such cases it is not uncommon for the lens after a time to become opaque, but the loss of perception of light will restrain any careful surgeon from attempting to remove it.

Choroidal sarcoma.—A tumour producing detachment of the retina must in most instances spring from the choroid, and will probably be a sarcoma. In any such case symptoms of more or less discomfort about the eye, and of more or less disturbance of vision, will probably have existed prior to the occurrence of the detachment, and a state of high tension can hardly fail to exist. An attempt to puncture such a detachment would, of course, carry the needle through the tumour, and would be likely to rouse it into increased activity, besides forming an opening through which it would readily escape from the eye. The presence of high tension would generally preserve the surgeon from so dangerous an error, and when the presence of a tumour is determined, or is even highly probable, the best course will be to remove the eye without delay, or to perform Mules' operation. I have lately pursued the latter course, and after some months have had no reason to be dissatisfied with the results. The sclera seems incapable of supporting the recurrence of a morbid growth, and recurrence in some other organ would scarcely be rendered less probable by enucleation. I have performed Mules' operation in one case of detachment from a spindle-celled, and in one from a melanotic sarcoma, and in neither has there been any appearance of return.*

The retina itself is only liable to one kind of morbid growth, a form of medullary cancer of extreme malignancy, springing from the connective tissue or neuroglia, and commonly called glioma.

Retinal glioma is a disease of early life, and I have seen a case in which both eyes were congenitally affected, and in which attention was called to them by the fact that the infant was obviously blind. Usually it affects one eye only, and then, even if congenital, it may easily escape notice until it attains sufficient magnitude to alter the appearance of the eye. The first observation of parents is that the affected eye has a yellowish pupil, and that it is quite blind. At this stage I have known the condition mistaken for an opacity of the lens; but careful examination will reveal that it is occasioned by a yellow mass lying behind the lens. The distinction is not difficult, since the lens is a body with a very high index of refraction, which, when it is rendered conspicuous by an opacity behind it, is almost as bright as a diamond; whereas, when the lens itself is opaque, this brightness is dimmed or lost. By the time the growth becomes visible to the unaided eye, it will have materially increased the tension of the globe; and, as it will probably also be growing rapidly, it soon produces tensive pains and disturbance of the epithelium of the cornea. In a case left without treatment, the enlargement of the eyeball becomes rapid and correspondingly painful, ulceration occurs, a fungus protrudes and bleeds, and death by exhaustion follows a period of agonising and often protracted suffering.

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* See *Medical Press and Circular*, August 17, 1887.

As long as glioma is confined to the retina, and has not invaded the optic nerve, the eye may be removed with some hope of cure. A few successful cases have been recorded, in one of which I was the operator, and I kept the patient under observation for upwards of nine years. In the case of double glioma already mentioned I saw the patient with a hospital colleague. At that time, the baby being less than a month old, both retinæ were sprinkled over with yellowish-white spots of suspicious aspect. We advised and performed enucleation of one eye, in order to establish the diagnosis, and the specimen was pronounced to be glioma by a committee of the Pathological Society. We then recommended the removal of the second eye, but the parents refused consent. The child was brought to me again at the age of about four years, the glioma of the remaining eye having run its customary course; and in spite of removal of the contents of the orbit, in the hope of obtaining at least a temporary relief from pain, the little patient soon died. A post-mortem examination showed extensive cancerous disease within the cranium, extending through the optic nerve from the eye which had been left; while on the other side the optic nerve had undergone degeneration from the point where it was divided up to the chiasma, and no appearance of recurrence was to be found. If both eyes had been removed in infancy, I much doubt whether there would have been any return of the disease; and, as the child was blind from birth, the absence of the eyes would have been no loss.

In every case of retinal glioma, therefore, either enucleation of the globe or Mules' operation should be performed without delay. As I have already stated, I do not think the emptied sclera can afford the conditions necessary for the recurrence of a growth; and if I were satisfied that the disease was still limited to the retina, and had not penetrated into the trunk of the optic nerve, I should advise the latter proceeding. It must be remembered, however, that in Mules' operation the optic nerve is left at the level of the inner surface of the sclera; while in enucleation it may be divided half or three-quarters of an inch farther back. It is conceivable, and cannot be said to be impossible, that the operation might be performed at a time when the disease had indeed entered the nerve, but before it had travelled half an inch down the trunk; and in such a case the difference between the two operations might be one of life or death for the patient. Admitting that the conditions stated are not probable, yet the possibility of them would be held by most surgeons to turn the scale in favour of enucleation. If the nerve be divided in front of the limit which the disease has reached, recurrence in the orbit and extension to the brain will be the natural course of events; although even then the patient will be spared the suffering incidental to the slow distension and ultimate yielding of the eyeball.

The diseases of the choroid are not numerous, although they are highly important. The membrane is liable to be the point of origin of growths, mostly sarcomatous, which have been sufficiently referred to under the head of detachment of the retina, a symptom which they always produce. It often undergoes distension and wasting at the posterior pole of the eye, with evidences of secondary irritation or inflammation, in the high degrees of progressive myopia; and it is liable to disseminated patches of inflammation scattered over its surface, generally involving the retina, and often called by different names accordingly as the patches are larger or smaller. Inflammation commencing in the choroid has a much more speedy effect upon vision than inflammation commencing in the retina, because the latter may be limited to the connective tissue of the fibre· layer, and for a long time may not extend to any structure which is directly concerned in sight. The choroid, on the other hand, supplies the materials of nutrition to the perceptive layer of the retina through the chorio-capillaris, and hence its diseases strike directly at the integrity of the rods and cones.

Choroiditis.—Inflammations of the choroid are much alike in their general characters and results. They commence as patches of effusion, which give a dulled look to the portion of the eyeground which is affected, and which conceal the ordinary granular aspect. Such effusions in many cases slightly elevate the retina, and render its surface uneven, although not producing actual detachment, with the result that all images falling upon that portion appear to be distorted, on account of the distortion of the screen on which they are received. Patients constantly say that the lines of print appear to them to be wavy.

Coincidently with the effusion, there is generally a disturbance and excessive formation of pigment in and about the affected spot; and, as the effusion is absorbed, the spot where it was situate frequently undergoes atrophy, and the whole of the choroidal tissue is gradually removed, so as to reveal to the ophthalmoscopic observer the whiteness of the sclera. In early stages the white patch may be crossed by fragments of the choroid, remains of vessels, and so on; but the removal of these will ultimately be complete, and the place from which they have disappeared will almost always be bordered by a ring of pigment. A white spot on the background of the eye, framed in a border of pigment, is a characteristic sign of a patch of bygone choroidal inflammation.

The diseases of the choroid, as of other parts of the eye, present many points of analogy to those of the skin; and there is a form of choroiditis, commonly called "disseminated," which is met with (or, rather, the relics of which are met with) in children who are the subjects of inherited syphilis, and which looks as if the membrane had been the seat of a crop or succession of pimples. The eyeground is rather thickly strewn with small white spots of the kind already described, each bordered with black, and presenting a very striking picture. I have never seen this form of the disease in the effusion stage, which may possibly have occurred prior to birth, but the spots are frequently associated with cases of inherited syphilis in which the sight, after recovery from keratitis, is less good than the state of the cornea will explain. There may be a multitude of such spots without blindness, and their importance depends mainly upon whether they are in the equatorial region, or extend also to the neighbourhood of the yellow spot.

In the choroiditis of adult age the patches are larger than in the disseminated variety, and the effusion stage is often met with. It is not uncommon to see all stages in the same eye at the same time, *i.e.* effusion, partially absorbed effusion, progressive and complete atrophy, and the irregular heaping up of pigment. The eyeground in such cases presents a curiously mottled and variegated aspect. The disease is often obstinate, and is apt to expend itself much upon the equatorial region, where it can do less harm than elsewhere. Extension to the region of the yellow spot, with consequent loss of central vision, is always possible, and the eye cannot be called safe until there has been no trace of fresh effusion for a considerable time. Complete blindness does not often occur, since some portion of the retina generally escapes; but, if the region of the yellow spot be invaded, the patient will probably lose the power of reading and writing, or of following any occupation. I have seen a gentleman reduced to this condition, and unable to see anything he looked at, who had nevertheless preserved sufficient of the lateral parts of the field of vision to be able to guide himself.

I attach very little importance to the subdivisions of choroiditis which have been made by writers, and which, in most cases, appear to me to be shadowy and unreal. The point of importance is that we have to deal with a serious disease, which, if not controlled, may bring about the most disastrous results.

Perhaps half the cases of choroiditis occur in patients with a definite syphilitic history. When such a history can be traced, it is prudent to begin the treatment with full doses of iodide of potassium, and to proceed afterwards to a course of mercury on the principles already laid down. When syphilis cannot be traced, nor even on any good ground suspected, it is proper to commence the treatment with mercury, which in such cases need not be continued after recovery appears to be complete.

It is, of course, useless to waste treatment upon the mere remains of an old choroiditis, the relics, so to speak, of a past storm; and therefore, in examining a case, it is desirable to dilate the pupils fully, and to scrutinise every part of the eyegrounds with the greatest care. In old cases there will generally be great disappearance of pavement epithelium, with consequent general visibility of the choroidal stroma; but if, besides this, there is nothing to be seen but white patches, bordered by pigment, and separated by interspaces of transparent retina, through which the presence of the choroid can be distinctly seen, the observer is only looking at the scars which former disease has left behind. If, on the other hand, the transparency of the retina, or the visibility of the subretinal structures, is anywhere veiled by effusion, then active mischief is still in progress.

The irregular pigmentation of choroiditis is readily distinguished from that of pigmentary retinitis. In the latter, as already mentioned, the retinal vessels are partially buried or concealed; in the former they usually cross in front of the pigment patches and retain a perfectly sharp outline. There are, nevertheless, certain cases which can only be described as "retino-choroiditis," in which the retina clearly participates in the affection, and in which migration of pigment, sometimes in such a manner as partly to conceal blood-vessels, takes place into its tissue.

In many cases of non-syphilitic choroiditis, and in others in which there was an unquestionable syphilitic history, I have found the existence of great nervous exhaustion, which in some has appeared to be at least partly due to masturbation. When this habit or its consequences are in operation, benefit will generally follow from keeping the skin of the penis blistered for a time; and, whenever there is nerve exhaustion, it is desirable to combine iron with either the iodide of potassium or the mercury, and to secure all possible advantages in the way of food, exercise, and general habits.

As long as any choroidal effusion remains, and for some time after its disappearance, the strictest rest of the eyes must be enforced, no reading, drawing, or occupations requiring sight being permitted; and the eyes should be protected from strong light, either natural or artificial, by dark blue glasses of sufficient size and of such shape as to come close to the margin of the orbit. It will often be well to use a weak lotion of physostigmine, which will not only exclude light by contracting the pupil, but will also diminish any tendency to high tension which might arise from inflammatory hypersecretion.

In all suitable cases local depletion should be employed, and repeated, or not, according to the progress of the case and the condition of the patient. Counter-irritation should also be practised, either over the mastoid processes or on the temporal region, or on these alternately, the object being rather to maintain a moderate effect than to produce a troublesome sore. By the methods here indicated, or by some combination of them, many instances of choroiditis will be conducted to a successful issue. It is obvious that the general health will require careful attention, that the state of the excretions must be investigated, and that temporary departures from the treatment, or modifications of it, may from time to time be called for by various symptoms. When necessary, it will be easy to combine other tonics besides iron with the mercury, such as quinine, cod-liver oil, or arsenic, and I have frequently administered the last-mentioned remedy with advantage.

The disturbance of the choroid which occurs in the immediate vicinity of the optic nerve, and which has been described under the formidable name of "sclerochoroiditis posterior," is mostly, I believe, mechanical in its origin and essential nature, although it may become complicated by inflammation in certain circumstances. In nearly all myopic eyes, and in some that are hypermetropic or astigmatic, the nerve is bordered, on one side or all round, by a white crescentic line, or by a white circle, which is seen by careful examination to consist of a denuded portion of sclera, in front of which the choroid has disappeared. This condition is primarily brought about by the yielding of the posterior hemisphere of the eye under the stress of excessive convergence; and the whole question will be fully dealt with in the chapter on refraction, to which the reader must be referred for further particulars.

Hæmorrhages into the choroid are sometimes met with, but they are less frequent than retinal hæmorrhages, although not always easy to be distinguished from them. The effused blood passes easily through the loose meshes of the choroidal stroma, and deepens the colour of the space over which it is poured out, and which therefore appears as a dark patch on the eyeground. Over this dark patch the semi-transparency of the retina is more manifest than elsewhere, and may form a sort of faint film over the blood. A choroidal hæmorrhage which detached the retina, or seriously disturbed the chorio-capillaris or the pavement epithelium, would certainly produce a blind spot corresponding to the position of the effusion; but a hæmorrhage in the deeper layers would not of necessity greatly interfere with vision. In all such cases an exact diagnosis can only be reached by a careful comparison of the ophthalmoscopic appearances with the defects of sight revealed by the answers of the patient. The treatment of choroidal would be conducted on the same lines as the treatment of retinal hæmorrhage; and, unless the local injury gave rise to atrophy, with perhaps slightly better prospects of success.

Coloboma.—Just as, in coloboma iridis, the choroid sometimes participates in the defect, and sometimes preserves its continuity, so there may be coloboma of the choroid co-existing with perfect formation of the iris. The deficiency extends downwards from the entrance of the optic nerve, reaching nearly or quite to the equator; and behind it the sclera is usually weak and bulges backwards, forming a depression into which the retinal vessels sink with visible curves. The edges of the choroidal gap are frequently somewhat pigmented, and the appearance can hardly be mistaken for any other condition. The sight is seldom equal to that of the sound eye (supposing the defect to be monocular), but is seldom much impaired; and it will be found that the disturbance of the retinal curve, due to the scleral protrusion, is often attended by some degree of astigmatism. The defect is, of course, congenital, and, while it has no tendency to change for the worse, it does not admit of treatment.

The posterior hemisphere of the sclera can scarcely be said to be subject to any other form of disease than the distension from which it suffers in cases of progressive myopia, and in which the portion immediately external to the margin of the optic nerve is sometimes thinned out, bulged backward, and stretched to a very remarkable extent. Such a condition is necessarily attended by wasting of the choroid over the affected region, and is recognised ophthalmoscopically by the bending back of the retinal vessels, or of any remains of choroidal tissue, over the white patch left behind, where most of the choroid has disappeared. The treatment of this stretching resolves itself into that of the progressive myopia by which it is produced, or of the choroidal irritation or inflammation by which it may be attended. The condition does not admit of being improved, but in favourable cases any increase of the extension may be prevented. R. B. C.

CHAPTER X.

AMBLYOPIA AND AMAUROSIS.

It was the custom of writers in the pre-ophthalmoscopic period to use the word "amaurosis" to express any form of blindness the cause of which could not in those days be discovered; and to use the word "amblyopia" to express a defect of vision less than blindness, for which likewise no explanation could be afforded. These words retain their meanings and some measure of utility, although the sphere of their applications has been greatly curtailed.

In carrying out the systematic examination of the eyes, and of the state of the visual function, described in chapter ii., it will sometimes be found that the eyes, or more frequently that one eye, may be deficient in natural acuteness of sight, although nothing can be discovered by which this deficiency can be explained. Such a condition is not uncommon in squint arising from hypermetropia, the squinting eye being the one affected; and the same thing occurs also in hypermetropia, especially of rather high degree, in which there is no squint. After all possible correction with glasses, we may find that one eye has nearly normal vision, while the other can, perhaps, only see large objects; and we may not find any manifest reason for the defect either in the refracting media or in the structures of the eyeground. The explanation commonly given of such cases is that the partially blind eye has for some reason been disused from birth, and that the amblyopia arises from the retina having never been called upon to exercise its function. This view derives some support from the fact that in a few cases great improvement will be produced by systematic exercise; but, on the other hand, it is very rare to see any appearance of nerve atrophy, a condition to which complete disuse might not unnaturally lead. In some of these cases the affected eye is hypermetropic in a higher degree than its fellow, so that, unless provided with a lens, it would never come into work in ordinary circumstances. The stimulus to the exercise of accommodation in hypermetropia is the instinctive desire to obtain clear images, and this stimulus acts from the centre equally upon both eyes. As soon as the eye with the lesser amount of hypermetropia is sufficiently accommodated to give clear vision, the stimulus is satisfied, and the more hypermetropic eye is never brought into the condition for seeing acutely as long as the other is open and in use. A somewhat similar effect is produced in unequal myopia, in which it often happens that objects of vision are habitually held at the most convenient distance for the eye which has the lesser degree of the defect, and hence that they are not brought near enough to allow the eye with the greater degree to see them with distinctness. In all such cases it is probable that the unconscious exercise of the defective eye, in affording a defensive field of vision on its own side, may save it from degenerating into complete blindness, while the want of definite exercise of its central portions may suffer it to lapse into amblyopia. The same argument would apply to cases of squint in which the deviating eye is practically disused, and for this reason it is my custom to operate for the cure of squint at any age, however early, if amblyopia of the squinting eye exists, in the hope that its restoration to correct position may enable it to work in harmony with its fellow. Where there is no squint, and the amblyopic eye is more hypermetropic than its fellow, it should be systematically and daily exercised in reading with the aid of a strong convex lens, and if it improves under this treatment it may ultimately be brought to unite with its fellow in binocular vision.

Even when one eye has perfect vision for all ranges and the other is amblyopic, even to a high degree, it is important, especially in young subjects, that the latter should be compelled to work to the limits of its power. For this purpose the sound eye should be covered or closed, and the patient should be provided with a convex lens of about six dioptres, with the help of which he should spell out words of the smallest type which it enables him to see. This exercise should be continued daily for perhaps ten minutes at a time. If, after the lapse of a month, there is no improvement, it will hardly be worth while to persevere; but if by that time a smaller type can be read than at the beginning, or if the same type can be read more easily, the training should be continued as long as improvement follows. The chief stimulus to the necessary perseverance is the possibility that, in the chances of life, the better eye may be injured by accident or disease, a consideration which plainly renders it desirable to preserve the defective one in the best attainable condition. It must be remembered that a person with one eye blind, or nearly so, is more exposed than others to accidental injury on that side, and therefore, other things being equal, to the occurrence of sympathetic ophthalmia.

An amblyopia without visible change is to be met with in some cases of night blindness occurring in persons who have lived in tropical climates, and in whom it may be inferred that the retinæ, accustomed to the stimulus of a very strong light, lose the power of responding to a weaker one. These cases are distinguished from pigmentary retinitis not only by the absence of the characteristic markings in the retina, but also by the absence (in good daylight) of any contraction of the field of vision. As soon as daylight fades, however, not only does the central vision sink in a marked degree, but great limitation of the field is also to be expected, so that persons who have excellent vision by daylight may be unable either to read or to go about with safety after dusk. Night blindness is hardly amenable to treatment, but it has no tendency to become worse. It may even undergo a considerable degree of improvement in the course of time, the eyes recovering more or less of their normal sensibility.

Amblyopia may sometimes form an element in the various maladies of the hysterical, or it may be simulated by military malingerers, or by persons who are seeking to recover damages from a railway company for injuries sustained in a collision.

Hysterical amblyopia may be infinitely varied in its forms, sometimes central, sometimes peripheral. It may generally be detected by the history, by the character of the patient, and by the changes in the symptoms from time to time. If the tests be judiciously varied, and if the field of vision be carefully taken by the perimeter, the patient will scarcely ever be able to preserve identity of symptoms in successive examinations. The variations, coupled with the character of the invasion, and the absence of changes in the eyeground, may generally be taken to be conclusive.

Simulated amblyopia can only be detected by a combination of all the various methods of testing the ocular function, and by close comparison of the objective with the subjective symptoms. The surgeon must remember that persons who enter upon an attempt at simulation are almost certain to have read up the characters of the condition which they simulate; and any endeavour to detect them must be conducted with extreme care, and without any appearance of incredulity concerning their assertions. A shock to the nervous system from a railway accident is undoubtedly sometimes followed by genuine amblyopia; but in all such instances, as far as my experience extends, changes in the optic disc or retina will be discovered by careful examination in the direct method, even when the lesser enlargement of the inverted image may fail to display them. If such changes are discovered, it will not be easy to question the good faith of the sufferer; but if the ophthalmoscope shows nothing, every other method of testing the truth of his statements should be employed. It is easy so to arrange a stereoscope that it will display some object only to the eye said to be affected; and, if this object is seen, an important piece of evidence is obtained. If, both eyes being open, a prism of four or five degrees be held before one eye, preferably with its base upwards or downwards, it will duplicate the images of any object looked at, a convenient one for the purpose being a candle flame at about eight feet distant. If the patient can be made to see double by placing a prism before the professedly sound eye, he must obviously be seeing with the other; and if the two images are of equal intensity, he will be seeing equally well with both. A still better test is that of Professor Snellen, in which the object is a word composed alternately of red and of green letters. The letters should be transparent, and are conveniently arranged like a magic lantern slide, so that the word can be hung up against a window and seen by transmitted light. They should be large, so as to be easily and distinctly legible from the selected point of view. The person under examination is then fitted with a trial frame having before one eye a piece of green glass of such a tone as to quench the red letters absolutely, and before the other eye a piece of red glass of such a tone as to quench the green letters absolutely. When these are fitted, the parti-coloured word should be suddenly exposed to view, and the subject asked to say what he sees. Suppose the word to be F*R*I*E*N*D*, with the block letters red and the italic letters green, and that the patient, who professes to be blind or dim-sighted of his right eye, has over it a red glass, and over the left a green one. If he were of equally good sight in both eyes he would see the red letters with the right eye, and the green letters with the left, but he would have no power of analysing his perception, and, seeing all the letters, he would see the word "friend." If he were really blind of the right eye, he would not see the red letters at all, but only the green ones; that is, he would see the word "red;" and if he were blind of the left eye, he would see the red letters only, that is, the word "fin." If the case were not one of blindness, but only of dim-sightedness of the affected eye, the patient might see the entire word, but the letters of one colour would be better defined and more conspicuous than those of the other. It is hardly possible for a malingerer, if this test is dexterously applied, and if he is called upon to answer quickly to the question of what he sees, to avoid the betrayal of his imposture.

Amblyopia may sometimes be associated with conditions of nerve anæmia, or of nerve exhaustion, arising as parts of some more general malady; or it may occur in the course of fevers, or of some of the exanthemata, and may in any of these cases be permanent, or may terminate in recovery. Complete temporary blindness has been met with as a precursor of epileptic attacks, and has followed the administration of large quantities of quinine. It has also been met with as a consequence of protracted exposure to intense light, as in some of the cases which have been described as "snow-blindness." All the foregoing conditions are of rare occurrence, and do not possess any great degree of practical importance.

It is quite otherwise with a form of amblyopia which affects first the centre of the field of vision, the patient often saying that there is a cloud floating before his eye, through which he sees but dimly, and which may probably increase in density and in magnitude from day to day. Before such a cloud produces blindness to form, it often produces blindness to colour, first to red and green, afterwards perhaps to blue and yellow. In such cases it is desirable to use with the perimeter not only a white object, but also a coloured one, and to determine the boundaries of the defect for each. When no perimeter is at hand, a piece of coloured paper may be fixed to the end of a pen or pencil, and moved into and across the field. Some writers maintain that a central colour defect of oval shape, with its longer axis horizontal, is characteristic of tobacco amblyopia. The cases of tobacco amblyopia which I have recognised, and in which the diagnosis was justified by the result, have been attended by some pallor of the optic nerves, with no effusion or blurring of their outlines, and by perfect knee jerks. By the last-named symptom the cases have been discriminated from early stages of locomotor ataxy, to which, as far as the state of the optic nerves and vision were concerned, they bore a great resemblance. My colleague, Mr. Frost, who has seen a large amount of tobacco amblyopia among out-patients, is of opinion that in the earlier stages the disc margins are a little hazy, and that this condition is succeeded by pallor of the outer half of the nerve. Drs. Samelsohn and Uhthoff have had opportunities of examining microscopically the eyes of patients suffering from tobacco amblyopia who died from some intercurrent malady; and they describe an increase of the interstitial connective tissue in that portion of the nerve which contains the fibres from the region of the yellow spot, and say that in cases of long standing these fibres may be completely atrophied. Their account seems hardly compatible with the restoration of vision which usually follows the abandonment of tobacco.

In testing sight in cases of central defect, the vision for near objects, *i.e.* for a book held in the hand, will often be found reduced in greater proportion than the vision for distant test types. The reason of this is that eccentric parts of the retina may afford considerable help in deciphering single letters, but not much when the thing to be done is the recognition of a word as a whole.

The causes of central visual defect may be very numerous, and many of them may be of such a nature as scarcely to admit of being obviated. Excesses of various kinds (frequently of several kinds in the same individual), excesses with women, or masturbation, the excessive use of alcohol (especially in the form of ardent spirit) and of tobacco, will account for a considerable proportion of the cases, and for many which are scarcely amenable to any form of treatment. Not only have the victims broken constitutions, but they seldom have sufficient self-control to be able to enter seriously upon the business of amending their lives. In so far as the malady has been brought on by overwork and privation, there may be good ground for expecting amendment as soon as these and all other prejudicial influences can be set aside.

The most serious cause of central visual defect is, however, the form of neuritis which is described at page 313, and which commences behind the eye. When this very insidious and dangerous malady is suspected, active treatment should be practised without delay.

When the central area of vision is still normal, we may nevertheless find large gaps in the field, so that there may be complete blindness as regards images which fall upon certain parts of the retinæ; and these defects have of late years come into prominence in connection with the localisation of intracranial growths and other diseases. The anatomy and distribution of the nerve fibres subservient to vision have been made the subjects of much experimental and anatomical research, but many questions concerning them are still unsettled. It is supposed, however, that the brain centres of the visual function are seated in the occipital lobes and the angular gyri of the cerebrum, and that fibres pass forwards to form the optic tracts, which blend in the chiasma, and issue from it in a new combination as the optic nerves. It is believed that the fibres of the right tract proceed to the temporal half of the right retina and to the nasal half of the left, those of the left tract to the temporal half of the left retina and the nasal half of the right, and that both tracts send fibres to the yellow spot of each eye, so that vision of objects situated on the left of the spectator, and seen by the right halves of his two retinæ, is due to conduction through the right tract, and vision of objects on the right of the spectator is due to conduction through the left tract, while central vision is due to conduction through both.

It follows that any intercepting lesion situated in the right hemisphere, between the cerebral visual centres and the chiasma, may cut off conduction through the right tract, and produce loss of function of the right half of each retina, or of the left half of each visual field; while, conversely, any intercepting lesion in the left hemisphere, between the cerebral visual centres and the chiasma, may destroy the function of the left halves of the retinæ, and occasion loss of the right half of each field. It is easy to imagine, moreover, that any such intercepting lesion may be so conditioned as to arrest conduction through some fibres and not through others, thus producing a limited area of right- or left-hand blindness, such as the loss of a quadrant of the field instead of the loss of all of it.

On the other hand, no lesion interrupting only one tract can cause central blindness, because conduction through the other tract would still be preserved. It is found, as a matter of fact, in all cases of hemiopia due to brain lesion, that the boundary line of the remaining field of vision, although it may coincide with the vertical meridian of the field both above and below, transgresses it to a small extent at the fixing point.

Whenever, therefore, we find loss of part, or of the whole (with the exception of the immediate centre) of the field of vision on the left side, we may infer the existence of a lesion between the chiasma and the cerebral visual centre on the right side ; and whenever we find a similar loss of the field of vision on the right side, we may infer the existence of a similar lesion on the left.

If the field of vision be lost on different sides in the two eyes (that is, the outer half of each, or the inner half of each) the lesion can hardly be elsewhere than in the chiasma. If central vision be lost, as well as some peripheral portion, the lesion is probably in the optic nerve of the affected eye, part of the fibres remaining unaffected. It may, however, be in the chiasma, and sufficiently extensive to affect the axial fibres proceeding to both nerves.

The lesions affecting half of the field of vision are very numerous, comprising intracranial tumours of all varieties and in many positions. Some such tumours, especially the gummata, are readily dispersed by sufficiently active antisyphilitic treatment; others may admit of removal by operation, and others may be malignant. The most complete information concerning the present state of a very difficult and intricate question, many parts of which are by no means settled, will be found in Dr. Ferrier's work on "The Functions of the Brain."

It is a matter of familiar observation, that pressure upon the eyeball, or a blow on the head in its neighbourhood, is attended by a subjective sensation of light, presumably due to the actual shock sustained by the retinal elements. A somewhat similar phenomenon is sometimes experienced in connection with severe headaches, in the shape of an appearance of sparks or coloured lights before the eyes; and I have heard the same thing described by people past middle age, in whom the arteries were probably of defective elasticity, as a consequence of sudden exertion. We may assume that a powerful wave of blood entering the eye communicates a shock to many parts of the retina at once. Persons subject to migraine will sometimes describe various transient appearances of light or films, or floating clouds; and one form of these appearances is sufficiently common and sufficiently definite to have received the name of "teichopsia," from the fancied resemblance of the outline of the appearance to the salient and re-entering angles of a fortification. The appearance commences as a tiny spot, which enlarges and moves towards the periphery of the field, assuming a definite outline as a zigzag curve or crescent formed of concentric lines of different colours. The crescent disappears on reaching the periphery of the field, but others may form in immediate succession to the first, and the appearances are usually succeeded by a paroxysm of headache of great severity. The retinal pathology is unknown, the affection does not appear to entail any risk to sight, and its treatment must be that of the species of migraine of which it forms a part.

R. B. C.

CHAPTER XI.

COLOUR VISION AND ITS DEFECTS.

Normal colour vision.—The transmission of light is effected by means of transverse waves in a hypothetical medium, called ether. It consists therefore not in the transportation of palpable particles, but in the propagation from point to point of a change of form, or in the arrangement of particles, just as occurs in the ripples which radiate from a pebble thrown into the water.

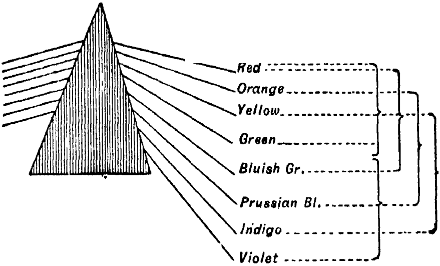


Fig. 50.

Solar light appears to be uniform and colourless, but it contains waves of different lengths, which, when isolated from each other, give rise to different visual sensations, which are the origin of all our ideas of colour.

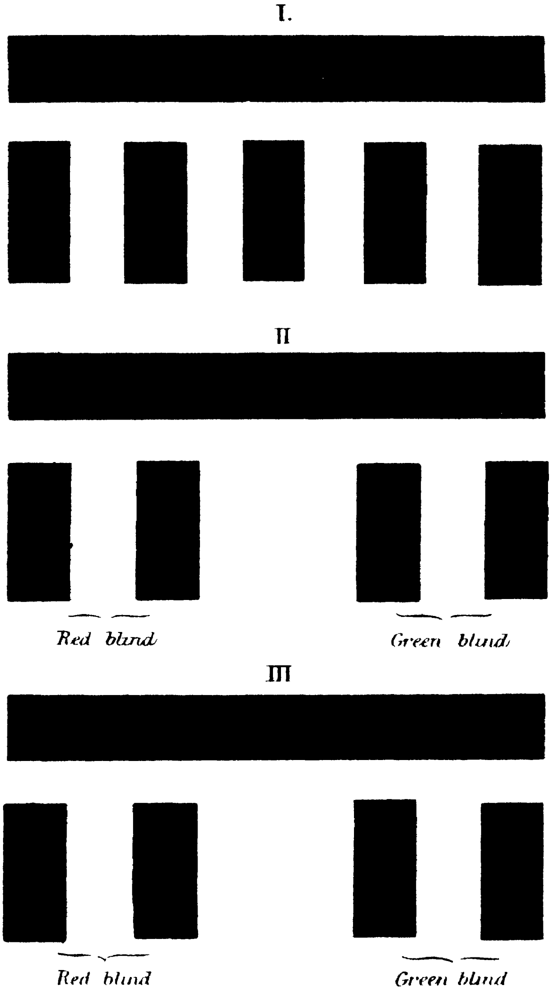
Since the refrangibility of the different rays is proportionate to the shortness of their waves, a beam of white, *i.e.* colourless, light on passing through a prism becomes spread out fan-wise, or "dispersed," so that

PLATE.

This illustrates the mistakes made by the colour-blind, but must not itself be used as the test object.

I., II., III., represent the test colours, and beneath each are arranged the "confusion colours."

MISTAKES OF THE COLOUR BLIND
(after Holmgren)



its constituents become arranged in regular order according to their wave-length.

If the beam so dispersed is thrown upon a screen, a many-coloured band or "spectrum" is produced, as in the diagram (Fig. 50).

If the beam be passed through another prism turned in the opposite direction, its elements are again united and white is reproduced.

Throughout the spectrum the colours shade off gradually into one another, the naming therefore of only certain hues as "spectrum colours" is somewhat arbitrary. For instance, "bluish-green," which is not generally included, has as great a right to be as orange, which is obviously a compound of red and yellow. It is, indeed, certain that our primary colour sensations are limited to three, or at the most four, and that all others are combinations of these.

The colour-sensations indicated in Fig. 50 have certain relations to each other which permit of their being arranged in pairs, in the manner indicated by the brackets.

If members of these pairs be seen simultaneously or in extremely rapid succession, white is produced. Hence these colours are said to be complementary to each other. They have other relations to each other, which have led to their being called "contrast colours;" thus if the one is looked at for a few seconds an "after-image" of the complementary colour is seen. A minute black or white surface upon a coloured background generally appears to be of the complementary colour to the latter. Complementary colours not only will not mix to form another colour, but we cannot even conceive of their mixing. A greenish-red involves in our minds a contradiction of terms, although we know at once what is meant by a greenish-blue or greenish-yellow.

It will be seen in Fig. 50 that green is connected both with red and violet; its complement is therefore the colour formed by their union, namely, purple, which does not lie in the spectrum. The connection of one colour with two others involves no inconsistency when it is considered that the spectral colour is not the same throughout; for instance. the red nearest the yellow contains a considerable quantity of the latter, while at the other end it is purer.

All objects reflect some light and absorb or quench some. Those which reflect nearly all the waves of one length, but absorb nearly all others, appear to us of the colour of the reflected rays.

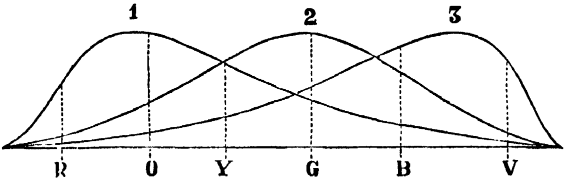


Fig. 51.

The following are the two theories of colour vision most generally accepted :

The Young-Helmholtz theory assumes the existence of three sets of elements within the eye, stimulation of each of which gives rise to a fundamental colour sensation. These correspond to red, green and violet (or blue according to some). But each colour, in addition to acting upon its own elements, to a less extent affects the other two. This is indicated in Fig. 51, in which the three curves stand for the three primary colour sensations of red, green and violet. The initials on the lower line indicate the spectrum colours, while the height of each curve opposite each of these shows the extent to which the corresponding element is affected by that colour. When all three sets of elements are excited, the sensation of white is produced.

Hering's theory.—It has been known for some years that in the retina there exists a coloured substance (the visual purple), whose colour is removed by exposure to light, but becomes restored in the dark. This theory assumes the existence of three somewhat similar substances, each of which is acted upon in opposite ways by contrast or complementary colours. The one is destroyed by white light, and restored by black; the second is acted upon in opposite ways by red and green, the third by yellow and blue. All colours act upon the black-white substance, but the red and green do not act at all upon the yellow-blue substance, nor *vice versâ*. If two contrast colours act simultaneously their effect upon the colour-perceiving substance is neutralised, and only their action on the black-white remains.

According to this view, white is not the sum of two complementary colour sensations, but merely the result of stimulation of the black-white substance when the two colour sensations have neutralised each other. Black, too, is looked upon as a definite colour sensation, while the Young-Helmholtz theory considers it merely as a negative sensation, *i.e.* the absence of light.

Defective colour vision.—It has long been known that some persons possessing vision that is otherwise normal, fail to distinguish between colours which to most people are quite dissimilar. They are accordingly said to be "colour-blind;" in reality, their vision is only defective for certain colours. In the present day the existence of a congenital defect of colour vision is of the greatest importance, owing to the universal employment of red and green signals, since it is these colours which the colour-blind chiefly mistake. The result of an examination of a large number of persons has been to show that congenital deficiency of colour sense exists in about 4 per cent. of adult males, but that in women it is extremely rare.

The nature and degree of the defect vary very much. In the majority of cases the most marked feature is a difficulty in distinguishing certain shades of red from certain shades of green. Of shades of the two colours which to the normal eye appear to be of equal intensity, the red will appear the brightest to one class of these colour-blind (called the "green-blind") and the green to the other (called the "red-blind"). In the worst cases the colours are indistinguishable from each other under all conditions; in others they are only confused when the illumination is rather feeble, or when the colours themselves are much diluted with white. In these cases blue and yellow present no difficulty. In another rarer class of cases these are confounded, but red and green cause no difficulty.

On the Young-Helmholtz theory, defective colour vision is explained by the absence, or functional inactivity, of one set of elements, and the effect can be depicted diagramatically by eliminating one of the curves in Fig. 51. For example, if curve 1, representing the red elements, be omitted, red and green would stimulate the remaining curves almost in the same relative proportion; but since the total stimulation is greater with the latter colour, it will appear the brighter. According to this theory, there may be complete or partial red-, green-, or violet-blindness.

According to Hering's theory, blindness for one of the primary colours is impossible without there being also blindness for the contrast colour; hence we should speak of "blue-yellow" or of "red-green" blindness, and assume that it depended on the absence or inertness of one of the colour-seeing substances. Thus if the red-green substance were inert, an absolutely pure red or green would only act on the black-white substance; but there are no pure colours in nature, and the red-green blind would class either of these with blues or yellows, according as they contain one or the other colour.

Testing colour vision.—The state of colour vision cannot be measured by making the subject of the test name the colour of substances, for in the first place there may be normal colour sense, and yet from defective education the colour may be wrongly named. In the second place, the naming of a colour correctly gives no clue as to the subjective sensation which it excites. A colour-blind person may see reds and greens as different shades of the same colour, but may have learnt that what seem to him to be rather sombre shades of this colour are called red by others, while the brighter tints are called green; he may therefore name the colours correctly, and even believe that he sees the true difference between them, and unless the trial is repeated several times, and with a variety of shades, detection may easily be escaped. In this way a colour-blind guard or pilot may interpret signals correctly to which he has been accustomed; if, however, they are dimmed by rain or mist, or if, from the distance being unknown, he is unable to compare the intensity of a red and green light, he may mistake the one for the other.

A test of colour vision should be independent of naming the colours; it should be sufficiently exhaustive to preclude the possibility of evasion by chance or guessing, and should be sufficiently rapid to permit of large numbers of persons being examined in as short a space of time as possible; these requirements are all fulfilled by Holmgren's coloured wools.

The test consists of three parts; the first enables us to discover the existence of defective colour vision, the second to detect its nature, while the third is merely confirmatory.

In the first stage the examinee is given a test colour, a skein of a rather pale green, a grass-green much diluted (*see* coloured plate), and there are spread out upon a white cloth in a good light a number of other skeins, consisting of all shades of green, as well as greys, drabs, pinks and yellows, all considerably diluted with white; the examinee is then told to pick out from the heap those skeins which appear to him to be of the same colour as the one held by him, but without regard to differences in shade. If he chooses all the greens and no other colours, he has normal colour vision; if this is defective, he will choose one or more of the "confusion colours," shown in the plate, and he must be put through the second test.

In this the test colour is a dilute purple- or rose-colour (*see* coloured plate); as it is composed of red and violet, the red-blind matches with it blue and violet. For the green-blind a combination of red and violet produces grey, and green has a similar effect; hence he chooses these confusion colours. If the examinee fails in the first test, but succeeds in the second, he has a weak colour sense, but is not totally blind to one of the fundamental colours.

In the third test a bright red (*see* coloured plate), such as is used in signal flags on railways, is the test colour; the red-blind matches with it dark green and dark brown, the green-blind with brighter shades of these colours.

Congenital colour blindness is quite incurable.

Failure of colour sense occurring as a symptom of affections of the optic nerve and retina, has been considered in the preceding chapter.

W. A. F.

CHAPTER XII.

INJURIES.

INJURIES of the eye are of importance, because upon their proper treatment often depends the sight not only of the injured eye, but also of its fellow.

Foreign bodies.—Of superficial injuries the most common is the entry of a small foreign body between the lids. It may become implanted on, or embedded in, the cornea, or may lie upon the conjunctiva; perhaps the most common situation is beneath the upper lid, about 3 mm. from its edge. With every movement of the lid it is scratched against the cornea, and if it be of a gritty nature, considerable irritation results.

Whenever a patient comes with conjunctival injection of one eye, which has come on suddenly, a suspicion of its being due to a foreign body should be aroused; but unless the examination is properly conducted, the latter, though present, may easily be overlooked. The cornea should be carefully examined by focal illumination, the surgeon altering his position so that the light may be reflected from the cornea at different angles; for some particles are not easily seen against an iris of somewhat similar colour, while others again are not well seen against the pupil. If nothing is found on the cornea, the lids must be everted and examined.

A particle of iron after its removal from the cornea often leaves behind a deposit of rust, which may easily be mistaken for the foreign body itself. The distinction can, however, always be made if the examination be conducted by focal illumination, and a magnifying lens used, for the rust is only deposited where the iron has been exposed to the action of the air or tears; hence when the foreign particle has been cast off, a ring of rust having a clear centre is left. This deposit is usually thrown off in a few days, but if thought desirable, it can be removed entire, just like a foreign body.

When a foreign body has lain upon the cornea several days, it is generally surrounded by a halo of greyish colour, due to inflammatory exudation.

A foreign body on the palpebral conjunctiva is easily removed with the wet corner of a handkerchief, or by passing the spud beneath it and lifting it off. When it lies on the cornea, its removal is equally easy, provided that the patient will keep the eye steady. The cornea is, however, exceedingly sensitive, and care must be taken that when the spud touches it, a sudden movement of the eye does not cause an extensive abrasion. The surgeon should stand behind the seated patient, whose head rests against his body. The lids should be held apart with the index and ring fingers of one hand, the middle finger pressing against the globe, while the other hand manipulates the spud. No attempt should be made to use any instrument until the eye is fully under control. Owing to neglect of this precaution, I have frequently seen abrasions of the cornea produced, which constituted lesions many times more serious than would have resulted from the minute foreign body, which still lay untouched. Now that complete anæsthesia of the cornea can be produced by cocaine there is less excuse for such an accident, and general anæsthesia is seldom necessary even in the case of children when their confidence can be gained.

When a foreign body has not penetrated beyond the epithelial layer, there is no difficulty in removing it by passing the edge of the spud beneath it and raising it. When it lies in the substance of the cornea, the same proceeding will often suffice; it is, however, sometimes necessary to use a sharp needle which can be passed beneath it.

After the removal of the foreign body a few drops of castor oil, combined, if necessary, with cocaine, or the cocaine ointment (Formula 34), afford much relief by forming a protecting covering for the abrasion.

As a rule all inflammation begins to subside as soon as a foreign body has been removed, but sometimes when it has remained embedded in the cornea for some days, and there is considerable infiltration of the adjacent tissue, pus is formed between the corneal lamellæ, or in the anterior chamber. The treatment of these complications has been considered on page 167.

Burns of the conjunctiva are often caused by acids, caustic alkalis, or unslaked lime. A slight burn causes a shedding of the epithelium, and catarrhal ophthalmia, which may last a few days. In more severe burns, the conjunctiva looks white immediately after the accident, and its whole thickness may be thrown off as a slough, leaving an ulcer which takes some time to heal. Usually the corresponding conjunctival surface of the lid is burnt also, and when this is the case symblepharon, or adhesion of the lid to the globe, nearly always results, especially when the burn extends into the cul-de-sac.

If seen soon after the accident, care should be taken to wash away every particle of the caustic agent with a stream of water. Theoretically it might seem advisable to neutralise the acid with an alkali, and *vice versâ;* practically the time that would be lost in procuring the required solution is far better occupied in washing the eye. Lime becomes slaked almost immediately, and the mechanical irritation produced by its gritty particles is often the most noticeable effect; such particles, from their number and small size, are often difficult to remove.

A burn of the cornea causes it to assume a dull white colour; this is due to the condition of the epithelium, and it is usually impossible to form an opinion as to the depth to which the burn has extended. Unless it is limited to the epithelial layer, a permanent opacity will result. Little can be done in the way of treatment except to soothe the pain by cocaine or iced compresses; when the slough has been thrown off, the case is to treated as one of corneal ulceration.

Abrasions of the cornea, which may be so slight as only to be visible on the most careful inspection, are yet extremely painful, owing to the exposure of the nerve filaments. They are to be treated in the same way as the lesion which results from a foreign body. In a healthy subject they heal rapidly, and usually leave no scar. Such injuries are, however, not unfrequently inflicted upon women during lactation by the infant's finger-nail, and in the old and ill-nourished men employed by the parish to break stones. In such cases onyx and hypopion not unfrequently result. (*See* page 167.)

Penetrating wounds of the cornea, if peripheral and not very minute, are usually accompanied by protrusion of the iris. If central, the lens is very liable to be implicated. All injuries which open up the interlamellar spaces of the cornea are more likely to be followed by suppuration when catarrhal or purulent inflammation of the conjunctiva, or inflammation of the lacrymal sac, is present.

The prolapsed iris, if unreduced, becomes adherent to the wound, towards which there is generally some displacement of the pupil, whose shape is distorted. In these circumstances the direction of the fibres of the iris usually shows that some traction is exercised upon it, and the mobility of the pupil is somewhat impaired. The dragging upon the iris may lead to repeated attacks of iritis in the injured eye, and to sympathetic irritation of its fellow.

If the case be seen within a few hours of the accident, an attempt should be made to reduce the prolapsed iris. Sometimes this can be done by friction with the forefinger, the lid being interposed between it and the cornea. More often it is necessary to dilate the wound by passing into it a small flat spatula, and turning this at right angles to the wound; the contractility of the iris will then sometimes draw the prolapsed portion in; reduction by either method is facilitated by the previous instillation of eserine.

A large prolapse has a tendency to recur, which cannot always be counteracted by eserine; the smaller ones are often more difficult to reduce owing to their tight strangulation, but they seldom recur.

When a prolapse cannot be reduced, or kept reduced, but is not more than a few days old, the prolapsed portion should be excised. When the wound is small, it should be enlarged, or a fresh one made at the sclero-corneal junction, and the iris just beyond the prolapsed portion should be seized, drawn out on one side and cut; slight traction should then be made, so as to bring out a little more iris at the other angle of the wound, where it should be cut quite close. In this way the excised portion is slightly larger than the actual prolapse, and the cut edges retract from the wound. Sometimes after the completion of the iridectomy there is still a small tag prolapsed at one or both angles of the wound; this must either be reduced with a spatula, or cut off. The operator has not attained his object until the iris is entirely free from the wound.

When the prolapse has existed a week or more, and has become firmly attached to the wound, the choice lies between leaving it alone, attempting the operation just described, or performing an iridectomy opposite the wound. When the inflammation is subsiding, the pupil not much displaced, and there is no evidence of dragging upon the iris, the prolapse may be disregarded. In the opposite conditions to these, the second alternative should be attempted, but it will often fail. When the chief trouble is likely to arise from the dragging on the iris, or the displacement of the pupil, and there appears no prospect of succeeding in freeing it from the wound, an iridectomy in the opposite direction is the best proceeding.

When the lens is wounded, it commences to become turbid within forty-eight hours. At the same time its volume increases, and by pressing forward the iris it may cause iritis, or, in an adult, glaucoma, by hindering the escape of fluid from the eye. Immediately after the injury, iced compresses may be applied to prevent inflammatory reaction. They are best made in the following manner: by the side of the patient's bed is placed a large block of ice; he is provided with two pads of cotton wool, one of which is laid upon the ice, and the other on the eye, and they are changed as often as the one in use ceases to give a sensation of cold. In all other respects the treatment of a traumatic cataract does not differ from that of one which has been needled. In a child the lens is usually absorbed; in the adult there is more risk of inflammation, owing to the more unyielding nature of the tissues.

When a wound passes beyond the cornea into the ciliary region, the risk of sympathetic mischief occurring is much greater, and this in proportion to the extent and irregularity of the wound, the puckering which it undergoes in healing, and the time occupied in the process.

As a rule an eye in which there is a large and lacerated wound of the ciliary region should be excised, supposing that the other eye is normal. When the wound is small and clean cut, the eye should be saved. In a doubtful case the decision will hang upon the complications present. When, together with a ciliary wound, there is a wound of the lens, an extensive loss of vitreous, or hæmorrhage into the vitreous, excision should be performed. The general principle of action to be followed is that no risk should be inflicted upon the sound eye for the sake of an eye which is not likely to possess any useful vision. When, however, the injury is of such a character that there is a fair probability of recovery with good vision, some risk to the other eye is justifiable. When it has been decided to endeavour to save a wounded globe, the wound, if gaping, should be accurately closed with sutures, which may be passed merely through the conjunctiva, or the edges of the sclerotic may be brought together with fine catgut. The case is then treated as any operation wound.

Retention of foreign body.—Wounds thus complicated are always serious. A foreign body in the anterior chamber can seldom be removed without excision of the portion of iris on which it rests, unless it should be a particle of iron, in which case it can sometimes be withdrawn by introducing the point of an electro-magnet. Indeed, cases have occurred in which the application of an inch bar-magnet connected with four Groves's cells to the outside of the cornea has caused the foreign body to retrace its course and emerge through the wound.

When a perforating wound of the cornea has been inflicted with a small fragment of metal, and there is also a wound of the lens, the turbidity of the latter renders it difficult to be certain whether the foreign body has remained in its substance, or has passed beyond it into the vitreous, or has even traversed the globe, and passed into the orbit. There is another alternative, which, although rare, must be taken into consideration, namely, that the foreign body may have wounded the lens through the cornea, and then rebounded. The magnet will sometimes indicate whether the fragment of metal is in the eye, by causing pain when held close to the eye in consequence of the traction exercised upon the tissues in which it lies.

In a doubtful case it is best to wait until absorption commences in the lens, when the particle may become visible, and be removed with the magnet. Or if it is not metallic, the softened lens matter may be let out by a free incision, in the hope that the foreign body may escape at the same time.

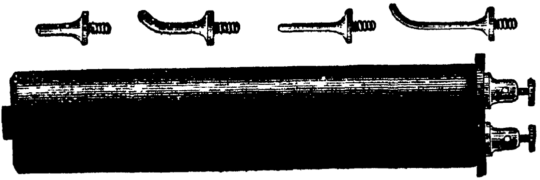


Fig 52.—Snell's Electro-Magnet.

When a fragment of iron is known to lie in the vitreous, and is visible with the ophthalmoscope, an attempt may be made to reach it with an electro-magnet, introduced through a scleral wound behind the ciliary region. The most convenient form is that designed by Mr. Snell (Fig. 52).

Many such cases have been successful; often, however, although the foreign body has been removed, the opacity in the vitreous which has followed the track of the magnet has prevented any useful vision being obtained; and in others cicatricial contraction has led to detachment of the retina and shrinking of the globe. In rare instances foreign particles have remained for many years in the vitreous without producing any irritation, and the experiments of Pagenstecher have clearly shown that it is not the foreign particle *per se* which causes inflammation, but the atmospheric germs introduced with it. Usually, however, severe inflammation, going on to suppuration, results. In other cases the inflammation is localised, and the foreign body becomes encapsuled; but even in such the contraction of the inflammatory exudation not unfrequently leads to detachment of the retina. It will be seen therefore that the retention of a foreign body within the globe is a serious matter, and unless there is fair vision, an absence of inflammation and of all complications, failure to remove it should be immediately followed by enucleation or an equivalent operation.

When a foreign body is partially embedded in the fundus, the chances of its shifting its position are lessened, and the difficulty of removing it with the magnet is increased. The following case, communicated to me by Mr. Brudenell Carter, is an illustration of the manner in which such a particle may become encapsuled and innocuous. "H. G., aged 18, was working with a chisel on a block of hard wood, in May, 1886, when the edge of the chisel broke, and a fragment flew off, striking him in the right eye. He went to Moorfields, where it was discovered that the fragment was embedded in the sclera of the posterior hemisphere, and he was advised to enter the hospital as an in-patient. He took alarm at some talk of enucleation, and came to me on the following morning. I found his right pupil artificially dilated, and there was a scarcely visible wound of the conjunctiva and sclera, just outside the ciliary region, and about halfway between the vertical and horizontal meridians.

There was no escape of vitreous. The piece of chisel had entered at this wound, and had passed in a direct line backwards, of course missing the lens, so that, when the eye was strongly abducted, it could be readily seen with the ophthalmoscope. Its track through the vitreous could not be traced, but there was a small effusion of blood where it had struck the fundus. The fragment appeared to be about a millimetre in width, and it projected about a millimetre from the sclera. There was no pain, very little conjunctival congestion, and scarcely any disturbance of sight. I directed the patient to return on the following morning, when I had prepared a sufficient magnet; but, on looking at the fragment, it was found to be obscured by an outpouring of lymph. Dr. Noyes, of New York, chanced to be with me, and he, having seen the case forty-eight hours before at Moorfields, was much struck by the extent to which the effusion of lymph had proceeded. There were no new symptoms, and I decided to await the course of events. In a short time the fragment became completely encapsuled, and all surface irritation in the vicinity of the external wound passed away. I saw the patient in July, 1887, fourteen months after the accident. The scar of the external wound had ceased to be visible, the position of the fragment remained the same, but it was so covered up that its precise nature could not be identified. It was surrounded by a small patch of choroidal atrophy with irregular pigmentation. Central vision was normal, and the blind spot left behind by the injury could only be discovered by very careful use of the perimeter."

When in this, or any other injury, primary enucleation is not performed, it should be done directly any great lowering of the intra-ocular tension indicates that the eye is beginning to shrink, or the appearance of a white reflex from the vitreous proves that this is extensively infiltrated with inflammatory exudation, and no vision can be looked for. When suppuration has commenced, some authorities recommend that enucleation should not be performed, partly because the risk of meningitis following the operation is believed to be greater when suppuration is present, and partly because suppuration is supposed to diminish the risk of sympathetic inflammation occurring. This latter belief formerly led to the occasional practice of purposely exciting suppuration in a lost eye, a practice that is, I believe, still sometimes adopted in veterinary surgery. Although, however, sympathetic inflammation occurs but rarely after suppuration, its occasional occurrence proves that this is not a sufficient safeguard. As regards the connection between intraocular suppuration and meningitis following enucleation, the evidence is not very conclusive; the complication is, under any circumstances, an exceedingly rare one, and the evidence, as far as it goes, seems to point to its being due to inoculation of the wound with the contents of the globe, rather than the acuteness or intensity of the inflammation.*

It is, however, for many reasons undesirable to operate during acute suppurative inflammation, since the inflamed and œdematous tissues do not always unite readily, and healing may consequently be delayed; the symptoms can be relieved by making a free incision into the cornea and evacuating the pus, enucleation being performed subsequently. The fact that suppuration has previously taken place does not, in the writer's opinion, render enucleation less necessary, but rather the contrary.

A **contusion** may injure the globe in many ways. The immediate effect of a blow on the eye or neighbouring bone is often to cause a sensation of light, from concussion of the retina or optic nerve. In rare cases there is impairment of vision without any ophthalmoscopic signs, lasting a few days. The cases in which permanent blindness follows contusions in the region of the orbit will be considered in chapter xv.

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* Nettleship, Trans. Ophthal. Soc., vol. vi.; Deutschmann, "Archiv f. Oph.," xxxi.: Wecker, *Annales d'Oculist*, 1886.

Hæmorrhage may occur into various parts of the eye. Sometimes a vessel of the iris is ruptured, and blood is poured into the anterior chamber (hyphæma); when only in small quantity, it sinks to the bottom of the chamber, and its upper boundary forms a straight horizontal line. When it is sufficient to fill the chamber, until time has been given for absorption to occur, it is impossible to form an opinion whether the hæmorrhage has occurred from the iris, or found its way forwards from the ciliary processes or choroid. In the latter case the eye would be lost; in the former, absorption of the blood would probably lead to complete recovery.

Hæmorrhage may take place into the substance of the retina or choroid (in which case it would be visible with the ophthalmoscope), or into the vitreous; in the latter case, if abundant, it may prevent any reflex being obtained with the ophthalmoscope. The symptoms and treatment of each of these conditions are considered in the chapters devoted to affections of the structures involved.

Occasionally a blow upon the eye causes luxation of the lens. This is most likely to occur in old people in whom the suspensory ligament is weak. If the dislocation occur into the anterior chamber, the nature of the accident is at once evident. The lens usually sinks to the lower part of the chamber, where it looks not unlike a drop of oil; there, filling up the angle between the cornea and the iris, it hinders the escape of fluid from the eye, and may give rise to glaucoma. A lens therefore dislocated into the anterior chamber should always be removed.

When dislocation takes place into the vitreous, the depth of the anterior chamber is much increased, the iris is tremulous, from having lost the support of the lens, and the eye shows all the signs of a high degree of hypermetropia. Sometimes the displaced lens can be seen in the vitreous, shifting its position with the movements of the eye. A lens may lie in the vitreous for years without giving rise to any symptoms, and then suddenly coming forward into the anterior chamber, set up acute glaucoma; more often, however, it sinks down, and resting on the ciliary processes sets up cyclitis. In any case it usually becomes opaque, and may undergo calcareous degeneration. When the suspensory ligament is ruptured on one side only, a partial dislocation of the lens takes place; this is indicated by its margin being visible in the pupil as a fine dark line having a regular curve, and that part of the iris being tremulous which has lost its support.

A blow on the eye may rupture the lens capsule, and thus lead to traumatic cataract.

A severe blow upon the eye may cause rupture of the sclerotic; this nearly always lies in the ciliary region, and is nearly concentric with the corneal margin. It is generally accompanied by free hæmorrhage into the globe, and requires enucleation. Occasionally the conjunctiva remains intact, but more often it also is torn. Sometimes the lens escapes through the rupture. When the conjunctiva remains entire, enucleation is not so necessary, as there is probably no risk of sympathetic inflammation occurring.

An accident more rarely met with is rupture of the choroid, the sclerotic remaining entire; this usually occurs behind the equator of the globe, the rent taking a curved course, with its concavity towards the disc. There is free hæmorrhage at first, so that the nature of the injury cannot be diagnosed; when this clears up, the seat of the rupture is indicated by a white band, caused by exposure of the sclerotic.

Sympathetic affections.—Injuries of one eye under certain conditions give rise to an affection of the other, which is then said to be "sympathetic;" the term has been so long in use that to change it would be inconvenient, but its use must not be taken to indicate anything as to the nature of connection between the affections of the two eyes.

There is no proof that a non-perforating lesion can produce sympathetic inflammation. On the other hand, any perforating lesion may cause it; but it is much more common after lacerated wounds of the ciliary region, especially when a portion of the uveal tract is included in the cicatrix. The liability to sympathetic affection seems to be diminished by suppuration occurring in the injured eye.

The symptoms may be divided into two distinct groups, which have a different pathology, run a different course, and often require different treatment. These are called respectively sympathetic neurosis and sympathetic ophthalmitis.

Sympathetic neurosis, or irritation, consists in an irritable condition of the second eye, which generally comes on soon after cicatrisation of the wound in the first, although its appearance may be long delayed. It is especially liable to occur if the globe is shrinking, and is frequently set up by eyes which have long been blind, and in which the choroid has been converted into a plate of bone. It may show itself in various ways; usually as an inability to use the eye, it becoming flushed and filling with tears when the attempt is made. Vision is usually normal, although it cannot be sustained; sometimes the accommodation fails; more rarely there is some contraction of the visual field. These symptoms are usually accompanied by some conjunctival injection of the injured eye. They often subside after rest, but are liable to recur. Sometimes these recurrences continue to take place at frequent intervals for many years, without the symptoms showing any tendency to get worse. The trouble is at once removed by excision of the injured eye, or even by severance of its ciliary nerves, which probably form the first link in the chain of reflex action by which the second eye is affected.

Sympathetic ophthalmitis is an inflammation of the second eye, caused by injury of its fellow. It affects chiefly the uveal tract; it never comes on earlier than three weeks after the injury, and shows itself as an iritis, which begins very insidiously, and usually without pain.

There are several types of cases; in the most severe the ciliary injection is considerable, and adhesions between the iris and the lens capsule form very rapidly. These not only unite the margin of the pupil with the lens, but glue their whole surfaces together; while the tissue of the iris itself is so much infiltrated with lymph that all details of its structure become unrecognisable, and it soon becomes atrophied, and of a pale or buff colour. Atropine produces no effect upon the pupil, the lens becomes opaque, thick membranous exudations from the ciliary body take place on its posterior surface, and the eye rapidly becomes blind. The disease often shows a tendency to undergo remissions and relapses; each attack, however, leaves the eye in a worse state than that in which it found it. In the mildest cases, attention is usually drawn to the eye by the patient complaining of dimness of vision. A faint ciliary blush is seen, and the cornea, if examined with a magnifying glass, is found to be studded over, especially its lower part, with minute brown specks, which lie on its posterior surface ("keratitis punctata"). The pupil acts sluggishly, and points of adhesion usually form. These, however, do not form so rapidly and are not so extensive as those just described. The media are usually clear, but occasionally a few fine opacities are visible in the anterior part of the vitreous. Not unfrequently there is a slight degree of optic neuritis, and in a few cases this is a prominent symptom. Many of these milder cases terminate in complete recovery. Between these extremes all degrees of severity are met with. The freedom from pain is usually a marked feature in sympathetic as compared with other forms of iritis.

Sympathetic inflammation occasionally does not make its appearance until after the exciting eye has been removed. In such cases the length of interval between the receipt of the injury and the affection of the second eye is probably not affected by the operation. The affection of the second eye is to be explained by assuming that at the time of the operation the morbid process had already extended beyond the point of section of the nerve. There is some evidence that these cases are, as a rule, of rather a mild type.*

The occurrence of sympathetic inflammation does not, as far as is known, affect the prognosis of the injured eye, although the fact that relapses of inflammation in the sympathising eye are commonly associated with conjunctival injection of the exciting eye, points to the possibility of the former reacting on the latter. As regards the prognosis of the sympathising eye, as a rule, the attack would appear to be the milder the earlier the symptoms appear. In other respects the forecast will be made on the same principles as for other forms of iritis, but is much less favourable.

Until recently the two above-described forms of sympathetic affections were considered as different stages, or different degrees of severity, of the same affection, and it was not until the difference between them was recognised that any true advance in the knowledge of their pathology became possible.

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* Trans. Ophth. Society, London, vol. vi.

The clinical history of sympathetic neurosis is consistent with its being of a reflex nature, the irritation being conveyed to the brain by the ciliary nerves of the injured eye, being reflected down the nerves of the other eye, and causing increased vascularity and secretion, or producing some change in the nerve centres, which renders them more sensitive to ordinary stimuli conveyed to them by afferent nerves, so that the mere exposure of the eye to light, or the muscular effort of accommodation, causes an irritation not unlike that produced by a foreign body on the conjunctiva.

The constant association function of the two eyes appears to favour their simultaneous innervation, and immediately after any slight injury of one eye, lacrymation, photophobia, and even conjunctival injection are not unfrequently seen in both, symptoms which differ probably in degree rather than in kind from those of sympathetic neurosis, which come on later, usually after cicatrisation of the wound.

Changes in the ciliary nerves have frequently been looked for, and occasionally found, but they are not sufficiently constant in their presence or in their nature to be of any value. The presence of a constant source of irritation, such as the pressure of a cicatrix upon the nerve, might produce reflex symptoms without the nerves involved showing any changes.

This reflex theory was at one time held to explain all sympathetic affections, and the fact that the injuries which were most prone to give rise to them usually implicated the region of the eye most thickly supplied with nerves, gave some support to it. There are, however, several difficulties in the way of accepting it for sympathetic ophthalmitis, for this occasionally does not make its appearance until after the removal of the injured eye, and if already present, is not appreciably affected by that operation. In fact, the clinical evidence is more in accordance with the view of a morbid change travelling slowly from one eye to the other by continuity of tissues, than that of a mere functional disturbance.

Nearly all the structures in the two eyes which can be shown to be in any way connected have in turn been considered as constituting the path by which the inflammation travels, and it has even been supposed that the second eye is affected through the general circulation, morbid particles of some kind being shed into this by the first eye, and selecting the other as their habitat in consequence of similarity of structure (Hutchinson). The theory that the inflammation travelled to the second eye through the optic nerves and chiasma is a very old one, dating as far back as Mackenzie, although he did not adopt it to the exclusion of others, as he is sometimes represented to have done. The theory as then held depended upon the supposed presence of nerve fibres passing from one eye to the other by the chiasma, the existence of which has since been disproved.

A study of the lymph streams of the optic nerves and the recent discoveries of the part played by micro-organisms in the production of disease, has led to what may be called the bacterial theory of sympathetic inflammation. The possibility of these microphytes being the cause of the infection of the second eye was suggested by Snellen, who pointed out that micro-organisms could always be found in eyes which had received perforating wounds, and been excised, an observation which has since been abundantly confirmed.

It has long been known that the intersheath space of the optic nerve was a lymph channel, and that the suprachoroidal space could readily be injected from it. It is curious that until recently the direction of the lymph stream has been a matter of uncertainty; this may be considered to have been set at rest by the recent experiments of Gifford, who introduced finely coloured particles into the vitreous of rabbits and observed the course taken by them. The result showed that there is an up lymph stream, from the eye to the brain, which accompanies the central vessels of the optic nerve, leaving the nerve with them and proceeding to the apex of the orbit; and that another down current passes along between the optic nerve sheaths.

As regards the influence of these facts on the pathology of sympathetic ophthalmitis, Deutschmann, and, more recently, Gifford, have made some important experiments. The former injected into the vitreous of one eye in rabbits cultures from the pyogenic micrococci; if the reaction in the inoculated eye was not too great, optic neuritis appeared after a few days in the other eye, and this was soon followed by the death of the animal. Examination of the parts then revealed micrococci in the vitreous and papilla of the second eye and in the sheath of both optic nerves. The inference therefore was, that they had travelled to the second eye along the optic nerve sheaths. Experiments with fluid and portions of the iris removed from the sympathising eye have in the human subject proved that cultures from them inoculated into rabbits' eyes produced the same course of symptoms. Gifford, repeating these experiments and using the spores of anthrax bacillus, in successful cases found similar conditions in the optic nerves; but from his previous experiments, and from the fact that the bacilli could be traced on the inoculated side along the vessels to the apex of the orbit, he concluded that they proceeded along these to the apex of the orbit, reached the brain, and thence passed with the lymph stream down both optic nerves.*

There are several objections that can be urged against this theory; one of these is, that it does not account for the special danger of wounds of the ciliary region. It is possible that the great number of vessels may have something to do with this; in one of Gifford's experiments the bacteria did appear to have passed along the walls of the perforating ciliary vessels to Tenon's capsule, and thence to have reached the nerve sheaths and the arteria centralis retinæ as it left the nerve. Although objections may be urged against it, it is at present the only theory in support of which there is any direct evidence. The objection that if it were true, basal meningitis ought frequently to occur, is met by assuming that stagnation and accumulation of the micro-organisms are necessary in order that they may excite inflammation, whereas in the brain they are immediately carried down the lymph streams of the optic nerves. This is consistent with the fact that the number of these leucocytes and of exudation cells increases towards the globe.

Any eye which is *likely* to set up sympathetic trouble must be removed or subjected to one of the operations which are believed to be equally efficacious. An eye which *may* give rise to sympathetic trouble must be removed when its vision is much impaired; if its vision is not at all impaired, it should be saved; between these limits each case must be judged on its own merits. Sympathetic neurosis can nearly always be cured by removal of the exciting eye, or severance of its nervous connections.

The treatment of sympathetic ophthalmitis must be considered in relation both to the exciting and the sympathising eye. Apart from the question of enucleation, it is extremely doubtful whether any treatment of the former has any beneficial effect upon the progress of the disease. There is a tradition that operative interference with this eye acts injuriously upon the sympathising eye, and may induce an exacerbation. There does not appear to be any evidence to support this view, and if it has been decided to preserve the injured eye, no measure which is required for that purpose should be neglected. When, however, the time for an operation can be selected, it would be well to postpone it till all active inflammation had ceased in the sympathising eye.

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* Some recent experiments by Randolph throw doubt on the accuracy of Deutchsmann's results, "Archiv of Oph.," 1888.

The treatment of the sympathising eye resolves itself into that of treating iritis; in the worst cases, however, atropine has little or no effect on the pupil, and an iridectomy is extremely difficult to perform, owing to the rottenness of the iris. The prognosis, although exceedingly grave, is not absolutely hopeless, even in the worst-looking cases; in these, after many remissions and relapses, the inflammation will finally subside; the lens by this time is usually opaque, the iris completely adherent to it and much atrophied; sometimes, however, if a passage can be made for the light, useful vision may be obtained. The best way of doing this is to perform a large iridectomy, and to remove the lens; neither step of the operation is, under the conditions, easy to perform; and even when both have been successfully accomplished, disappointment will often result from the presence of opacities in the vitreous or changes in the fundus. The effect of mercury is doubtful; to be of any use, it must be given early and thoroughly. Of the beneficial effect of keeping the patient in the dark, there can be no doubt.

It is doubtful whether the sympathising eye can react upon the excitant; the experiments above alluded to render it by no means impossible. The relapses of inflammation in the sympathising eye are often accompanied by injection of the exciting eye; but the latter is generally looked upon as the cause and not the result of the relapse. In any case, when the sympathising eye is blind, and the exciter possesses any vision, there is no doubt that the former should be removed.

Enucleation may be performed in the following way: an incision is made through the conjunctiva all round the cornea; each rectus tendon is in succession then raised by the squint hook and divided close to the globe; if the limbs of the speculum be now further separated, the globe springs forwards, and the optic nerve can then be divided by passing a stout pair of curved scissors behind the globe; the latter is now held between the thumb and index finger of the left hand, and all remaining attachments are divided. The conjunctival wound may be brought together with a suture, but this is quite unnecessary.

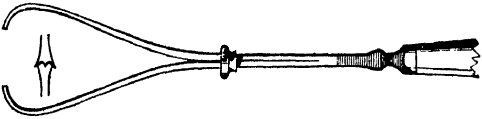

Fig. 53.—Sponge Holder.

Or the Vienna method may be employed; this consists in dividing one lateral rectus, then the optic nerve, and lastly the remaining recti, with the conjunctiva. This plan is much the quicker, but the muscles and conjunctiva are cut somewhat shorter. It will be found convenient to have at hand several small pieces of sponge fixed in holders which permit them to be readily changed (Fig. 53).

After the operation firm pressure should be applied with a pad and bandage; otherwise very extensive ecchymosis of the face is produced. Hæmorrhage hardly ever gives trouble; should it do so, the bandage should be reapplied, great care being taken that efficient pressure is made; if the bleeding still continues, all clots must be turned out and its source discovered; if it comes from the apex of the orbit a touch with the actual cautery at a black heat will generally check it, if there is a general oozing, the cavity should be syringed out with iced water, the largest Mules' sphere introduced, and firm pressure applied over it.

Very rarely, indeed, enucleation has been followed by meningitis.* In most of these cases there has at the time of the operation been acute suppuration within the eye; hence many surgeons will not enucleate when this is present. The meningitis is probably septic in character, and it would seem that inoculation of the orbit with the contents of the globe has some share in its production. In some cases symptoms which resembled those of commencing meningitis have subsided after freely washing out the capsule of Tenon, and providing for free drainage. It is a good precaution, therefore, in all cases to take the temperature regularly, in order to recognise the commencement of meningitis.

An artificial eye may be given about six weeks after the operation, provided that all irritation has subsided. The patient must be instructed to remove it every night. A new eye should be given as soon as the cornea becomes rough, as it does after a time from the action of the tears.

Substitutes for enucleation.—Various proceedings have from time to time been advocated, with the view of obtaining immunity from sympathetic inflammation, and either retaining the whole or a part of the injured eye. One of the oldest was the production of suppuration within the eye, it being a fact long known that the risk of sympathetic inflammation occurring is thereby diminished. Cases, however, have occurred to show that the immunity conferred is by no means absolute, and this mode of treatment is now universally abandoned.

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* For an abstract of all known cases *see* Trans. Ophthalmological Soc., vi.

Abscission consists in amputating the anterior segment of the globe, and closing the remainder by sutures passed through the sclerotic; in this way a better stump for an artificial eye is left than after enucleation. Occasionally, however, the choroid that is left becomes converted into bone, and then sympathetic neurosis usually follows. If, moreover, the bacterial theory of sympathetic ophthalmitis be accepted, such an operation cannot be considered an efficient safeguard against sympathetic ophthalmitis. This operation also has now been almost abandoned, and is never performed for conditions which may give rise to sympathetic trouble.

Evisceration or exenteration was proposed by Alfred Graefe, because he thought that it was accompanied by less risk of setting up meningitis. The operation consists in excising the cornea and a band of sclerotic about two millimetres wide, and then scooping out all the contents of the sclerotic, leaving its inner surface perfectly clean. The sclerotic and conjunctiva are then brought together with sutures. A solution of corrosive sublimate or other antiseptic being first used to syringe the cavity.

The occurrence of meningitis after enucleation is so exceedingly rare a complication that it will be long before it is possible to learn from experience whether evisceration offers any advantage in this respect; the arguments advanced in favour of such an hypothesis are far from being conclusive. All danger of sympathetic inflammation is supposed to be removed by the absolute removal of the whole uveal tract and the rendering of the cavity aseptic. Here, again, theoretical considerations are not convincing. The sclerotic is traversed by numerous blood-vessels, and if microorganisms were present in their sheaths, the possibility of their setting up sympathetic inflammation cannot be denied ; if, moreover, the inflammation travels slowly by continuity of tissue, the farther back the conducting track is severed the greater the safety. Mr. Cross has recorded two cases in which sympathetic inflammation followed, but in both the operation was performed at a date when the inflammation might have already travelled beyond the injured eye. (Tr. Oph. Soc. vii.)

Mules' operation.—With the object of obtaining a better support for an artificial eye, Mr. Mules has introduced the following operation. The first steps are the same as in evisceration. As soon as the sclerotic has been thoroughly cleaned, it is stuffed for a few minutes with morsels of sponge to arrest all bleeding, it is then thoroughly irrigated with an antiseptic, and a hollow sphere of glass or metal introduced. The sclerotic and conjunctiva are then united together over this with about three sutures, and the eye is dressed antiseptically. It is generally necessary to snip the sclerotic to give room for the introduction of the sphere, which should be of such a size that the sclerotic closes over it without any traction. Some pain, and swelling of the lids follow, which usually begin to subside about the third day, although sometimes an œdematous fold of conjunctiva remains for some time after the wound has healed. If this protrudes between the lids, it may be required to be snipped with scissors or scarified. Should failure of union occur at any point, the opening generally enlarges and the sphere escapes ; sometimes this can be avoided by removing it, refreshing the edges of the wound, and substituting a smaller sphere.

To retain the advantages both of Mules' operation and of enucleation, the writer lately adopted the plan of enucleating the eye, and then placing a glass sphere in Tenon's capsule, which with the muscles and conjunctiva are united over it. The thinness of the covering, however, renders it difficult to retain the sphere.

Division of the optic and ciliary nerves has also been proposed as a preventive of sympathetic mischief. Simple neurotomy can hardly be considered as likely to prove effective, but resection of a portion of the nerve has met with more favour. In view, however, of the bacterial theory, it can hardly be deemed efficient, since the microphytes can traverse the tissues which lie between the divided ends. If Gifford's views (page 381) as to the course of the lymph be accepted, there is no object in dividing the nerve farther back than the point at which the central vessels leave it. The operation is performed by exposing one of the lateral recti (by preference the internal), securing it by a double ligature and dividing it; the globe is then rotated so that the optic nerve comes into view; this is divided, and the globe having been then so much rotated that the posterior pole comes into the wound, all the structures are carefully dissected off this; the divided muscle is reunited, and the wound closed. The hæmorrhage is often considerable, and by infiltrating the cellular tissue it may cause the eye to protrude between the lids during the operation, and prevent its reduction. Suppuration in the orbit is another complication which may arise. On the whole, the general view taken of the operation is unfavourable, except perhaps for cases in which the patient refuses to submit to enucleation.

There is partial anæsthesia of the cornea as a rule for many weeks after the operation. Eventually the sensation is completely restored. Some observations of Poncet have shown that the recovery of sensation is due not to reunion of the divided nerves, but to new fibres growing forwards from the proximal end. W. A. F.

CHAPTER XIII.

ERRORS OF REFRACTION.

By the refraction of the eye is meant the influence which the organ exerts upon the course of rays entering it through the pupil; the action of the eye in regard to this is entirely passive and comparable to that of any other optical instrument. It is by virtue of that refraction that in the normal condition images of distant objects are formed upon the retina. To make the subject clear, a few introductory statements are necessary.

Optical principles.—Light from any luminous point, as long as it remains in the same medium, travels in straight lines, which radiate from that point in all directions; hence it is usual in diagrams to represent the course of light by straight lines called *rays*. Adjacent rays coming from the same point constitute a *pencil*. It follows that all rays in nature must be *divergent*, but their divergence will be the less the more distant their source. When we are concerned with rays that enter the pupil, we may consider as parallel, rays which come from a point distant not less than sixteen feet (five metres).

When a ray passes from one medium into another of different density, it is bent or "refracted" at the surface of separation. The number that expresses the relation that the refractive power of a substance bears to that of air (the latter being expressed by unity) is called the *index of refraction* of that substance.

Law of refraction.—In passing from a less into a more refracting medium, a ray is refracted towards the normal.* In passing from a more into a less refracting medium, it is refracted away from the normal. Rays that coincide with the normal undergo no refraction.

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* The normal is a line drawn perpendicular to the surface from the point at which the ray cuts it.

This is illustrated in Fig. 54, in which the ray A B C D in passing from air to glass is refracted towards the normal at B, and in passing from glass to air at C, away from it. When, as in the figure, the surfaces are parallel, the second refraction is equal in degree, but opposite in direction, to the first; consequently the ray undergoes no angular deviation, but simply *parallel displacement.*

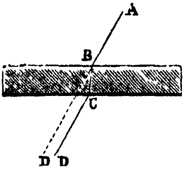

Fig. 54.—Refraction by a Medium with Parallel Surfaces.

When the surfaces are not parallel, deviation takes place, and if the law of refraction be applied in the case of a *prism* (Fig. 55), it will be found that the rays passing through it are refracted *towards the base of the prism.*

A spherical surface may be considered as formed by the juxtaposition of minute plane surfaces whose direction is such that their normals meet at one point, the centre of curvature.

Let $c\,d$ (Fig. 56) be a section of such a surface separating n, the less, from n', the more, refracting medium, and let k be the centre of curvature. Rays which are directed towards k undergo no refraction, since they coincide with the normal; the ray $a\ b$, which passes through k and through the centre of $c\ d$, forms the *principal axis ;* all other rays passing through k form *secondary axes.* The point of intersection of the axial rays is called the *optical centre.* In this case it is identical with the centre of curvature.

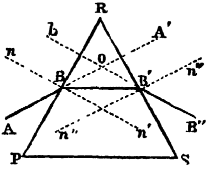

Fig. 55.—Refraction by Prism.
n' and n'' n'', the normals to the two surfaces: A B B' B'' course of a ray.

All other rays falling upon $c\ d$ would be refracted towards the normal. Rays, therefore, which were parallel in *n* to the principal axis would be rendered convergent, and would come to a focus on that axis in *n'*. The focus for parallel rays is called the *principal focus.* In the same way, rays parallel to any secondary axis would have their focus on that axis. The plane in which lie the foci of all the parallel

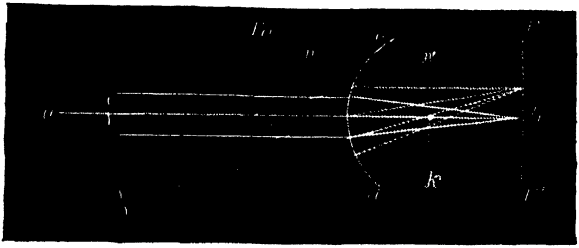

Fig. 56.—Single Refraction by a Spherical Surface.

pencils of rays falling upon *c d* is called the *principal focal plane* (F F').

The radius of curvature, *r*, of the refracting surface, and the indices of refraction, *n* and *n'*, of the media being known, the *principal focal distance,* F, *i.e.* the distance of the principal focus from the refracting surface, is found by the formula:

$$(1) \qquad F = \frac{r\,n'}{n' - n}$$

Rays which are parallel in *n'* would come to a focus in *n*; the position of this point F*a*, the anterior principal focal distance, is found by formula

$$(2) \qquad Fa = \frac{r\,n}{n' - n}$$

If, instead of being parallel, the rays in *n* came from some near point f (Fig. 57), and were therefore divergent, the same refraction would not bring them to a focus at F, but at some farther point f'. In the same way, rays from f' would have their focus at f; these points are therefore *conjugate foci* to each other, and the one is an exact counterpart or *image* of the other.

The position of the principal focus being known, the conjugate focus f' of any point f on the other side of the refracting surface can be found in two ways: (*a*) By the formula

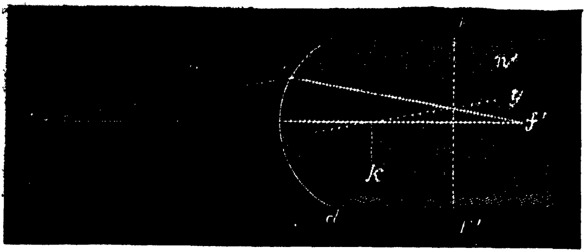

Fig. 57.—Conjugate Foci.

$$(3) \qquad \frac{1}{F} = \frac{1}{f} + \frac{1}{f'}$$

(*b*) By construction. In Fig. 57 draw a hypothetical ray $x\,y$, parallel to the ray $f\,c$, through the optical centre k; $x\,y$ will form a secondary axis, and, since $f\,c$ is parallel to it in n, it will cut it in n' in the principal focal plane F F'; it is only necessary to produce the ray until it cuts the principal axis to find the conjugate focus of f.

It will be evident that the nearer f is brought to the refracting surface, the farther will f' recede. When f coincides with the anterior focus, the rays will be parallel in n', and f' will therefore lie at an infinite distance. If f be brought still nearer, the rays in n' will be divergent, and hence will have no *real* focus ; if, however, they are produced backwards they will meet on the same side of the refracting surface as f. Such a focus is called *virtual.* The formula for finding f' must in this case be changed by giving to f' the minus sign ; it therefore becomes

$$(4) \qquad \frac{1}{F} = \frac{1}{f} - \frac{1}{f'}$$

Lenses are portions of highly refracting substance, usually glass, having one or both surfaces curved. They possess the property of altering the direction of rays that pass through them. Those with which we are at present concerned are called spherical, because one or both of their surfaces form part of a sphere.

A bi-convex spherical lens renders rays less divergent, and a bi-concave lens renders them more divergent, at each surface. A parallel pencil of rays will therefore be rendered convergent by the former and divergent by the latter.

The only ray that passes through such a lens without being refracted is the one that coincides with the principal axis, the line joining the centres of curvature of the surfaces (c^1 c^2, Fig. 58). But although there is no true optical centre, there are two " nodal points " k^1 k^2 which have this relation to each other, that a ray that is directed to one before, is directed to the other after, refraction, and only undergoes parallel displacement. Except with very thick lenses, or great obliquity of the incident ray, it is evident that no appreciable error would be caused by drawing the ray as passing without refraction through a point o, between k^1 and k^2; such a hypothetical point is called the *optical centre* of the lens, and all rays passing through it are *axial rays.*

The principal focus of bi-spherical lenses is found by the formula

$$(5) \quad \frac{1}{F} = \left(\frac{1}{r} + \frac{1}{r'} \right) (n' - n),$$

r and r' being the radius of curvature of the first and second surfaces respectively.

When the lens is of crown glass having a refractive index of 1·5, and the surfaces are of similar curvature, the above can be reduced to $F = r$. Usually, however, the refractive index is somewhat higher.

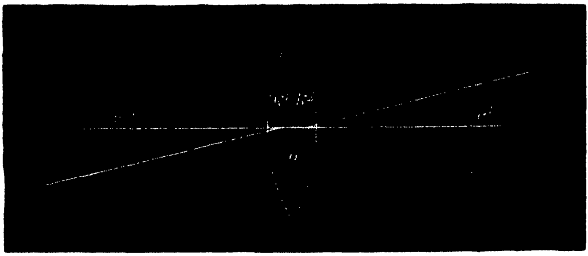

Fig. 58.—Nodal Points of a Bi-convex Lens.

Conjugate foci are found by formulæ already given (3 and 4).

Rays from each point of an object, being refracted by a lens, come to a focus; the sum of these foci produces an *image* of the object. When the image is formed by the actual meeting of the rays, it can be thrown upon a screen, and is said to be *real;* when it is only formed by a hypothetical prolongation of the rays, it is said to be *virtual;* a virtual image only becomes visible on looking *through* the lens.

The following statements as regards convex lenses can be verified by what has been said:

(1) When the object is more than twice the

principal focal distance from the lens, the image is smaller than the object, real, and inverted (Fig. 59, *a′ b′* being the object, *b a* the image).

(2) When the object is at twice the principal

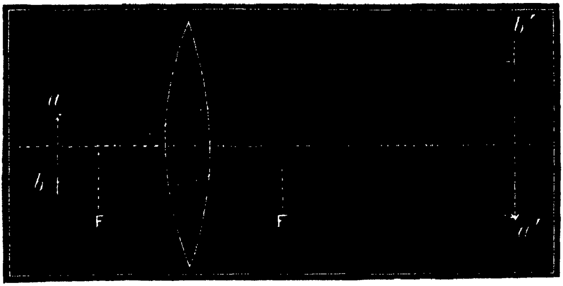

Fig. 59.—Formation of Real Image by Convex Lens.

focus distance, the image is of the same size, real and inverted.

(3) When the object is beyond the principal focal

Fig. 60.—Object at Principal Focal Distance.

distance, but less than twice that distance, the image is larger than the object, real, and inverted (Fig. 59, *a b* being the object and *b′ a′* the image).

(4) When the object lies at F, the rays after refraction are parallel, and no image is formed (Fig. 60).

(5) When the object lies nearer than F, the image is erect, virtual, and larger than the object, and would only be seen by looking through the lens (Fig. 61).

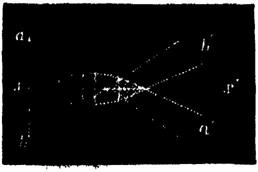

Fig. 61.—Formation of Virtual Image by Convex Lens.

With a concave lens the image is always virtual, erect, and smaller than the object (Fig. 62).

The clearness or definition of images formed by refraction is liable to be impaired from two causes:

(*a*) *Spherical aberration* is caused by rays which pass through the periphery of the lens being focussed sooner than the more central rays. This can be guarded against by using a diaphragm, or by employing a refracting surface having a parabolic instead of a spherical curvature.

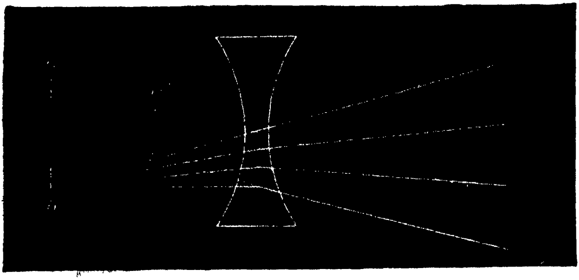

Fig. 62.—Formation of Virtual Image by Concave Lens.

(*b*) *Chromatic aberration* is caused by some rays, of which white light is composed, being more refrangible than others. It causes the edges of objects sometimes to appear fringed with colour. It can be prevented by using substances of different dispersive power in the construction of the lens.

The strength or refracting power of a lens may be indicated in several ways, of which only two are in general use. One of these is to number lenses according to their principal focal distance; thus we speak of a 4-in., 6-in., and 24-in. lens.* The power of a lens is, however, in inverse proportion to its focal length; hence in order to make these numbers represent the relative value of the lenses, it is necessary to convert them into fractions, $\frac{1}{4}$, $\frac{1}{6}$, $\frac{1}{24}$. The addition, however, of fractions is often troublesome, and the intervals between the higher lenses are of necessity very irregular, and the inch has a different value in different countries.

The other system in use is to take a very weak lens as the unit, and to number other lenses as multiples or decimal fractions of this. The unit taken is a lens of a metre focal length, and this is called a dioptre (1 D), a lens having twice this strength is 2 D, and so on; while a lens of half the refracting power of 1 D would be 0·5 D. The focal length of any lens is found by dividing a metre (100 cm. or 39·5 inches) by the number of the lens. Thus a lens of 2 D would have a focal length of 50 cm., or nearly 20 inches. This is called the metrical or dioptric system of numbering lenses. To find the value in dioptres of a lens whose focal length in inches is known, it is only necessary to divide 39½ by the focal length. Thus a 4-in., 6-in., and 24-in. lens would respectively be 10 D, 6·5 D, and 1·5 D nearly.

Convex lenses are usually preceded by the sign +. Concave lenses must be preceded by the sign −.

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* Strictly speaking, these figures were generally employed to represent the radius of curvature, which was usually a little greater than the focal distance.

The optical properties of the eye.—The eye consists of a closed, nearly spherical chamber, the posterior four-fifths of whose wall are formed by the opaque sclerotic, and the anterior fifth by the transparent cornea, which forms part of a curve having a much shorter radius of curvature (Fig. 63). The cavity of the globe is filled with fluid, whose index of refraction is 1·3365, and by a bi-convex lens whose index of refraction is 1·4371. Although the aqueous and the vitreous, which are separated by the lens, have different physical and chemical properties, their indices of refraction are the same, and they may therefore optically be looked upon as a single fluid. The surfaces of the cornea, except at its peripheral part, being parallel, its thickness may be disregarded, and it may be looked upon merely as the surface of separation between the air and the intra-ocular fluids.

If the refracting system of the eye consisted merely of the cornea and the intra-ocular fluid, rays falling upon the cornea would undergo single refraction, as in Fig. 56. The radius of curvature of the cornea being about 8 mm. the principal focal distance, as determined by Formula 1, would be 32 mm.

The length of the eye is, however, much less than this, hence the necessity for an increase in the refraction. This is brought about by means of the biconvex lens suspended in the intra-ocular fluid. The lens is suspended in its position by means of a membrane which blends with its capsule and peripherally is connected with the ciliary muscle; when the latter is in a state of relaxation, the membrane or suspensory ligament is in a state of tension, so that the lens is somewhat flattened. When the muscle contracts, the membrane is relaxed; the natural elasticity of the lens then causes it to assume a more globular form, and therefore increases its refractive power. This muscular act is called accommodation, because by virtue of it the eye is accommodated for a near-point.

The eye therefore constitutes a compound refracting system, having three refracting surfaces, the cornea and the anterior and posterior surfaces of the lens; and three refracting media, the aqueous, lens, and vitreous. The principal axis of this system passes through the centres of curvature of the surfaces of the lens, but does not usually quite coincide with the axis of the cornea; on it are situated the two nodal points, which are so close together that they may be considered as represented by an optical centre (o, Fig. 63) placed at the posterior pole of the lens. Rays therefore which pass through o will form secondary axes; all other rays will be refracted towards the secondary axis to which they are parallel. This will take place at each refracting surface, but it is convenient to regard only the course of the ray before its first, and after its final, refraction; and without introducing any appreciable error we may consider the rays within the eye as undergoing a single change in direction at a plane lying midway between the

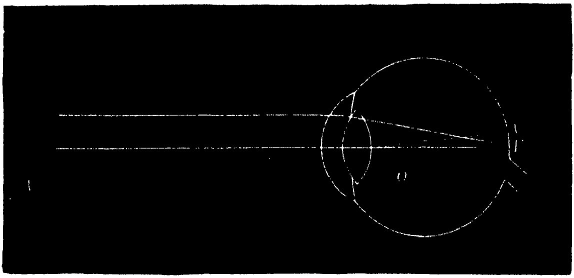

Fig. 63.
v v, Visual axis; o, optical centre.

anterior surface of the cornea and that of the lens, which may be called the principal surface.

There is one secondary axis which is of great importance; the most sensitive part of the retina is the fovea centralis, or the centre of the "yellow spot," which is situated nearly at the posterior pole of the eye; the sensibility of any part of the retina is in inverse proportion to its distance from this point. It is therefore important that the images of objects which we wish to see distinctly should fall upon the fovea centralis (v, Fig. 63). For this it is necessary that the axis on which it lies (v v), called the *visual axis*, should be directed towards the object.

For many reasons it is necessary to possess a standard of normal acuity of vision and a mode of expressing numerically departures from it. The method of ascertaining and recording this has been fully explained on page 39.

Strictly speaking, the visual acuity can only be measured after any existing error of refraction has been corrected, but in practice it is usual to indicate by "V" the patient's distant vision unaided by glasses, and this plan will be adopted in the following pages.

Snellen's types (Appendix A) extend in a continuous series from those which should be visible at 60 M to "semi-minion," which should be visible at 0·30 M. The smaller, or "reading types" are, however, not so well known as those of Jaeger, which are numbered consecutively from No. 1, which corresponds to 0·30 Snellen, to No. 20, which is identical with No. 12 Sn. These afford a convenient means of testing a patient's power of seeing near objects, but are not so well adapted for estimating the acuity of vision.*

The actual dimensions of the eye vary somewhat in different individuals, and in the same individual at different periods of life; an eye is, however, normal or *emmetropic* when the relation of its refraction to its length is such that parallel rays falling upon the cornea are focussed upon the retina when the accommodation is in complete abeyance. When the refraction departs in any way from this standard, it is said to be *ametropic.*

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* *See* Appendix A. Copies of these and other test types can be obtained from Messrs. Pickard and Curry, 195, Great Portland Street.

It must be understood that in speaking of the refraction of the eye, the accommodation is always to be considered as being in abeyance. We shall see later on that the action of the accommodation often introduces a difficulty in the diagnosis of the true refraction.

Accommodation.—We have seen that the emmetropic eye is adapted, when in a state of rest, for parallel rays, *i.e.* for infinite distance; indeed, it is a fact generally recognised that distance *per se* offers no obstacle to the vision of a normal eye. If an object is only bright enough, and large enough, it can be seen thousands of miles away, as is the case with the stars. The "far-point" therefore (which might be defined as the conjugate focus of the yellow spot) is in emmetropia at *infinity.*

To focus diverging rays the accommodation is necessary; the amount of accommodation which an individual is capable of using, steadily diminishes from the age of ten years, and at the age of sixty-five is *nil.* Slight variations also occur which depend upon the general condition of the health and the amount of work which the ciliary muscle is called upon to do. Thus an under-fed and overworked needlewoman who has been working for many hours in a bad light may be unequal to a sustained effort of accommodation which would present no difficulty to a robust individual.

The maximum amount of accommodation which the eyes are capable of using is called the "amplitude of accommodation;" it is the difference between the refraction of the eye when adapted for its far and near points, and is conveniently expressed by the lens which, placed in front of the eye, produces the same change in refraction. In emmetropia it is represented by a lens having its focal length at the near-point. For example, supposing that an emmetropic eye has its near-point at eight inches; a convex lens of this focus would render rays coming from this point parallel, as if they came from the far-point, and enable them to be focussed on the retina without the accommodation being used; in other words, it adapts the eye for a distance of eight inches.

Presbyopia is the name given to the condition in which the loss of accommodation, as the result of advancing age, is sufficient to remove the near-point more than eight inches from the eye. Since the loss of accommodative power is progressive from the age of ten, this definition is somewhat arbitrary, but it is practically convenient, for it is impossible without fatigue to use continuously more than half or two-thirds of the whole accommodation. A patient, therefore, whose near-point is at ten inches will not be able to hold the book or work nearer than about twenty inches, and then, owing to the small size of the retinal image, will either require a very strong illumination or a very large print.

The following table shows the amplitude of accommodation proper to each period of life, and the distance of the near-point when the eye is emmetropic. To correct the presbyopia in an emmetropic patient, it is only necessary to give convex glasses, which will make up the difference between the amplitude of accommodation that the patient possesses and 4·5 D. The near-point will thus be brought back to eight inches; the loss of accommodation will of course continue, but the correction given will usually suffice for four or five years. Thus a patient aged 50 would require 2 D (4·5—2·5), one aged 45 1 D (4·5—3·5), and so on.

REFRACTION AND ACCOMMODATION.
(*After Landolt.*)

Age.	Amplitude of Accommodation.	Distance of Near-Point.	
		Inches.	Centimetres.
10	14·0 D	2·8	7·0
15	12·0 ,,	3·3	8·3
20	10·0 ,,	4·0	10·0
25	8·5 ,,	4·6	11·7
30	7·0 ,,	5·6	14·0
35	5·5 ,,	7·0	18·0
40	4·5 ,,	8·7	22·0
45	3·5 ,,	11·0	28·5
50	2·5 ,,	16·0	40·0
55	1·75 ,,	22·0	57·0
60	1·0 ,,	39·5	100·0
65	0·75 ,,	52·6	133·0
70	0·25 ,,	157·0	400·0
75	0 ,,	∞	∞

Ametropia is a generic term including all conditions in which the retina does not lie at the principal focus of the dioptric system of the eye. When the retina lies in front of the principal focus, the form of ametropia is called *hypermetropia* (H, Fig. 64); when it lies beyond, it is called *myopia* (M). There is another form of ametropia, in which, owing to a departure from the spherical curvature in the refracting surfaces, the dioptric system of the eye has no true focus; this is called *astigmatism*.

Hypermetropia is usually due to the antero-posterior axis of the globe being abnormally short; it is then called *axial hypermetropia*. It may also be caused by a deficiency in the refractive power of the eye (*refractive hypermetropia*), as from flattening of the cornea or absence of the lens.

Axial hypermetropia is the normal condition of the eye at birth; the size of the globe should increase, at first rapidly, afterwards more slowly, until the condition of emmetropia is attained, which should occur before the age of eight years. As a matter of fact, a very large proportion of eyes, probably the majority, retain a very slight amount of hypermetropia throughout life. In some eyes the process of elongation continues beyond the production of emmetropia; the eye then becomes myopic, and the process must be considered as pathological.

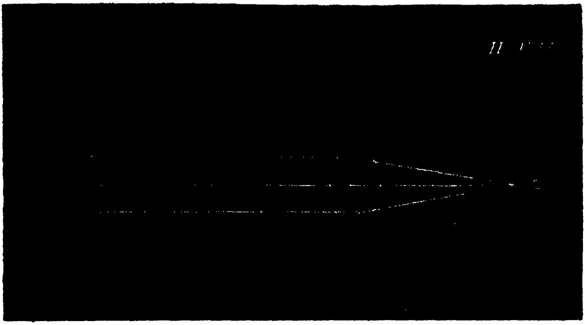

Fig 64.—Emmetropia, Hypermetropia, and Myopia.

In hypermetropia, since the retina lies in front of the principal focus, rays coming from the yellow spot are divergent on leaving the eye; hence the conjugate focus of the yellow spot (*i.e.* the *far-point* of the eye) is situated behind the eye at the point where they would meet if prolonged, and it is therefore negative and *virtual* (*pr*, Fig. 65). Conversely, the only rays that can be focussed on the retina are such as are convergent; but we have seen that there are in nature no such rays, hence a hypermetropic eye, with its accommodation relaxed, can have no distinct retinal image of any objects. If, however, the accommodation be called into play and is sufficiently powerful, parallel, and even divergent, rays can be brought to a focus.

If for the present we exclude the action of the ciliary muscle, it is evident that the only way in which parallel rays can be brought to a focus on the retina is by rendering them convergent before they enter the eye. This can be done by means of a convex lens, and this must be of such a strength, and so placed, that its principal focus, F, shall coincide with the far-point of the eye (Fig. 65). The strength of the lens that, placed close to the eye, brings parallel rays to a focus on the retina when the accommodation is relaxed, is the measure of the hypermetropia, and is said to "correct" it.

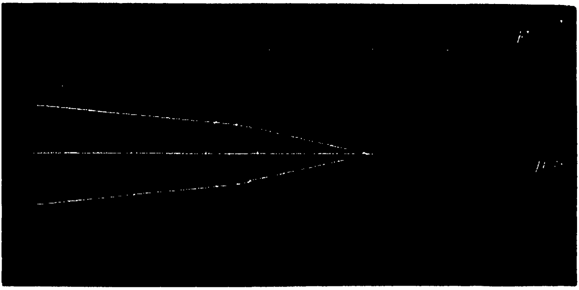

Fig. 65.—Hypermetropia: Course of Emergent Rays. Action of a convex lens.

Thus if a lens of + 5 D bring parallel rays to a focus on the retina, the eye is said to be hypermetropic to 5 D, and the far-point of the eye would be 20 cm. behind the correcting lens.

This method of indicating the amount of ametropia is not strictly accurate, since it takes no account of the distance of the lens from the eye; if this were 5 mm., the real hypermetropia would be $\frac{100}{20-5} = 6{\cdot}6$ D. But the first plan is practically convenient and universally adopted.

Since the defective vision which would otherwise result from hypermetropia can be overcome by the accommodation, and since the latter is an instinctive and almost involuntary act, a low degree of hypermetropia can exist without giving rise to any symptoms whatever. If, however, the amount be moderately high, or if the patient, from any cause, be unequal to a sustained muscular effort, symptoms will be produced.

In young people whose amplitude of accommodation is good, there is seldom any inconvenience experienced in distant vision; but a certain amount of the accommodation is used up in adapting the eye for parallel rays, and there is consequently less to spare for near vision; therefore such patients suffer either from defective vision for near objects, or from symptoms produced by the excessive muscular effort. Actual defect of near vision is seldom complained of except by hypermetropes whose ametropia is of high degree, or who are over thirty, and whose accommodation has consequently become impaired. The symptoms arising from excessive effort are much more common. These may consist in an inability to read or work for long together, especially towards evening, pain and conjunctival injection on making the attempt, and headache always brought on by prolonged use of the eyes. Occasionally this headache is the most prominent, or the only, symptom. This is more often the case at the age when the choice of a profession has been made, and severe mental work is required in preparing for a competitive examination. In such circumstances, owing to the culpable ignorance of the medical adviser and the apathy of friends, I have seen a young man throw up the chance of a brilliant professional career and take an Australian sheep farm, under the conviction that he was suffering from a mental incapacity which unfitted him for brain work, when the whole trouble could have been removed by wearing a pair of spectacles. In young children the book is not unfrequently held too near to the face, thus giving rise to a suspicion of short-sightedness. This is to be accounted for by the fact that when an object is brought nearer to the eye, and comes within the near-point, the size of the image increases more rapidly than the circles of diffusion. The child, finding it therefore impossible to obtain clear retinal images without a great muscular effort, prefers to obtain a large but ill-defined one.

Another symptom which in children not unfrequently occurs is convergent squint. This subject will be fully considered in chapter xiv. It is sufficient to say here that the necessary amount of accommodation can be used with less fatigue if a corresponding amount of convergence is used at the same time.

It not unfrequently happens that, in consequence of the strain thereon upon the ciliary muscle, it passes into a condition of tonic spasm, so that the eye is constantly accommodated for a near-point; under these circumstances some of the subjective symptoms of hypermetropia will be present, but on examination the eye will present most of the signs of myopia. The mode of distinguishing this apparent myopia from the true will be considered later on.

Myopia is usually caused by an elongation of the antero-posterior axis of the globe (*axial myopia*). But it may be due to an increase in the refraction of the eye, caused by excessive curvature of the cornea, an increase in the refraction of the lens, etc. (*refractive myopia*).

Owing to spasm of the ciliary muscle, parallel rays are sometimes focussed at a point in front of the retina, a fictitious myopia being thus produced.

Since the retina lies beyond the focus for parallel rays (M, Fig 64), only divergent rays can be focussed upon it. Conversely, rays coming from any point on the retina will converge on leaving the eye towards the axis on which that point is situated (Fig. 66), and will come to a focus at a distance which will be in inverse proportion to the degree of the myopia.

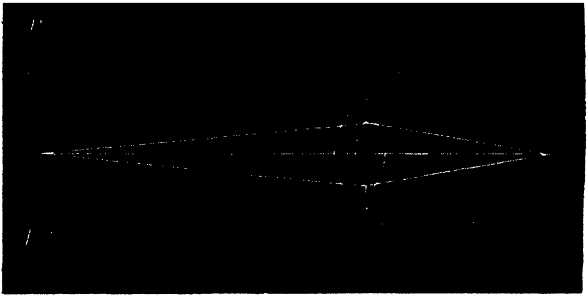

Fig. 66.—Myopia : Course of Emergent Rays. Action of a concave lens.

The "far-point" of the myopic eye is therefore positive and at a finite distance; and objects at that distance are seen without any accommodation being used. If a concave lens be placed in front of the eye (Fig. 66) so that its principal focus, F, coincides with the far-point *pr*, parallel rays will be rendered as divergent as if they came from it, and will then be focussed on the retina. Such a lens is said to "correct" the myopia, and is a measure of its degree.*

Myopia is very rarely congenital. It comes on as a rule during school life, and although in many instances there can be little doubt that there are structural peculiarities present in the eyes or orbits, which favour its development, yet it is probable that it may be produced in the growing eyes of children in whom no such defects exist, as the direct consequence of certain injurious conditions.

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* As before, the distance of the lens from the eye is disregarded.

Among the latter the most potent is the use of the eyes for near objects with insufficient illumination. To compensate for the deficiency in brightness, the child endeavours to increase the size of the retinal images by holding the face close to the book. Thus a larger amount both of convergence and of accommodation, and more extensive lateral movements, are required. This causes an increased flow of blood to the eye, and to this is added the passive congestion caused by the low position of the head, the compression of the veins of the neck, and the impeded respiration, which result from the stooping posture.

In this way the tissues of the tunics of the eye become hypervascular, and less fitted to resist the pressure of the intra-ocular fluid, while probably at the same time the latter is secreted in abnormal quantity. In these circumstances an inordinate increase takes place in the size of the globe, chiefly at the posterior pole, where it is unsupported by muscles, and where the sclerotic is weakened by the perforations of the ciliary arteries.

In all movements of the eyes, not only are the muscles directly concerned in any given action called into play, but all the muscles are in a state of tension. The globe is thus compressed between opposing forces, and tends to bulge at the posterior part.

When myopia has been established, some of the causes which led to its development are removed; for the accommodation is now required but little or not at all, while convergence is abandoned because of its increased difficulty, a difficulty that arises partly from its dissociation from accommodation, and partly from the proximity of the object. Hence the subjects of a high degree of myopia usually hold an object at which they are looking opposite one eye. The termination of school life and of the most active period of growth may coincide with the establishment of these conditions, and under such circumstances the myopia not unfrequently remains stationary. Although, however, in high myopia the accommodation is no longer needed, it does not follow that it is not used. Most myopes hold objects which they wish to see accurately within their far-point, and, as has been pointed out by Landolt,* when an object is held very close to the eye, a very slight change in its position necessitates a considerable alteration in the amount of accommodation required. It is extremely probable that frequent changes in the condition of the ciliary muscle may have a deleterious effect upon an eye which is already myopic. It has been thought that the reflected portion of the superior oblique may, by exercising constant pressure on the eye during the period of growth, cause it to become unduly elongated; and the fact that the amount and direction of this pressure vary with the prominence of the eyes and conformation of the orbitis, has been held to explain why under identical conditions some children become myopic, and others do not.†

In some cases the myopia continues to increase, and its progress is accompanied by changes in the tissues of the eye which seriously impair vision, and may lead to its total extinction. In these cases the stretching of the posterior pole is always accompanied by atrophic changes in the choroid on the outer side of the disc; as a result of these changes, the sclerotic becomes exposed to view over a crescentic area, the concavity of which embraces the disc. The presence of this "myopic crescent" is of little consequence as long as it is of small size; indeed, a similar crescent is occasionally met with in eyes which are not myopic, when it is more often situated below the disc. In the progressive form of myopia the atrophic area loses its crescentic form, its margin becomes irregular, and it extends in the direction of the yellow spot, while at the same time its base increases in breadth and embraces more and more of the disc, which it may completely encircle. Not unfrequently isolated patches of choroiditis, which pass rapidly into atrophy, appear at a little distance from the margin of the original crescent, and are swallowed up by its advance; in this manner a large, irregular, glistening white area is formed, on which may often be seen pigmented remains of choroidal tissue. When an extensive area of this kind is present, it always indicates a considerable bulging of the posterior pole of the eye ("posterior staphyloma"). Usually the direction of the disc is altered so that it faces more and more to the temporal side, and thus presents an oval appearance, with its long diameter vertical, when viewed with the ophthalmoscope.

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* "Refraction and Accommodation of the Eye," p. 452.

† Stilling, *Schädelbau und Kurysichligkeit*, 1888.

Besides the conditions described, the sclerotic round the optic nerve entrance is further weakened in myopia by a prolongation of the intervaginal space of the nerve into its substance; it is doubtful, however, whether this precedes the development of the myopia, or is caused by it. In axial myopia the ciliary muscle differs from that of the emmetropic eye in the preponderance of its longitudinal over its circular fibres.

As might be supposed, this destructive process, eating its way through a very vascular tissue, is occasionally accompanied by hæmorrhage. The increase of the proper vitreous substance not keeping pace with the increasing capacity of the globe, the medium becomes unduly fluid. It usually contains numerous floating opacities, and not unfrequently becomes detached from the fundus, when the retina, having lost its support, is very likely to do the same. The changes in the vitreous interfere with the nutrition of the lens, which may then become cataractous, the opacity usually commencing at the posterior pole.

Between stationary myopia and the progressive form just described, there are, of course, many grades, and it is not always possible, on first seeing a case, to say whether it will progress or not. The unfavourable elements in the prognosis are early onset and rapid increase, the presence of a large crescent and of irregularities in its margin, or of thinning of the choroid beyond it. The family history and general health and habits of the patient must also be taken into account.

It will be evident that the popular idea that myopes possess "strong" eyes is erroneous. Such eyes are always on the brink of disease; their condition is an unstable one, and is liable to be rendered worse by any serious impairment of the general health, or by their injudicious use. There are two apparent advantages of which myopes are often rather proud; the whole range of their vision being, as it were, pushed back towards the eye, they are enabled to hold objects much nearer than is possible to an emmetrope. In consequence of this, and also because of the greater length of the eyeball, they obtain very large retinal images, and can therefore see minute objects better than an emmetrope. In reality, it will be found that the actual acuity of vision is nearly always below the normal standard.

The other advantage that myopes claim, is that they do not become presbyopic as soon as others. A myope of 5 D has his far-point at 20 cm. (about 8 inches), and, as he seldom requires to see objects which are nearer than this, his accommodation is superfluous, and he will not feel its loss. In the slighter degrees the near-point gradually recedes from the eye with advancing years; but as it starts from a point abnormally near, it takes proportionately longer to reach an inconvenient distance.

It will be seen, from what has been said, that cases of myopia differ widely: some, after reaching a moderate degree, remaining stationary, and involving little inconvenience beyond the necessity of wearing glasses; while others become progressively worse throughout life, and are liable to various serious complications. It has of late become a question whether these two forms should not be looked upon as being distinct from their commencement, progressive myopia being considered as the result of an inflammation of the choroid, which both reduces the power of resistance of the ocular tunics, and increases the pressure upon them, by causing increased intra-ocular secretion; and the non-progressive form as the result of a process of evolution which is adapting the eyes more and more to requirements of near vision, upon which among civilised races they are chiefly exercised, and rendering them less fitted for distant vision.

Among savage races, whose eyes are used almost exclusively for distant vision, myopia is certainly very rare. In civilised countries, on the contrary, non-progressive myopia is exceedingly common, and statistics seem to show that it occurs in any given class with a frequency that is in proportion to its education. It is not uncommon also among nations such as the Chinese, whose civilisation is of ancient date, and who for many generations have used their eyes much for near vision, as is shown by the skill they have attained in carving, the character of their alphabet, and the existence of ancient writings.

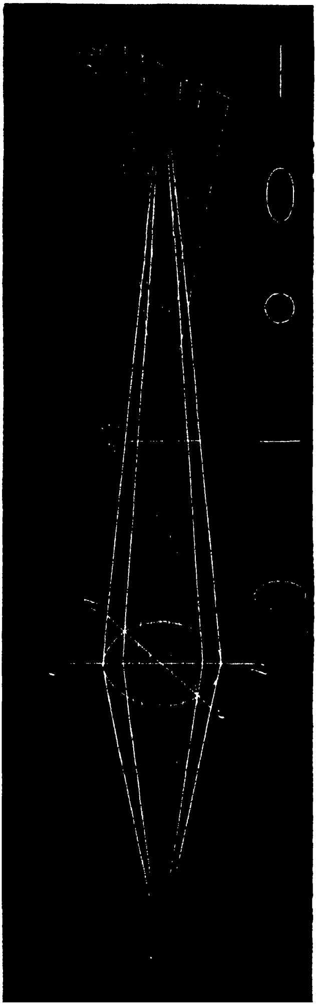

Fig. 67.

Progressive myopia, on the other hand, although rarer, does not seem to show the same preference for the educated classes, and occasionally makes its appearance before the school age.

Whatever influence the prolonged use of healthy eyes upon near objects may have on the production of myopia, there can be no question that the degree it attains can to some extent be regulated by attention to the details of lighting, position, etc.

Even if we admit that the inflammatory process which results in progressive myopia, often possesses its sinister character from the commencement, yet we cannot doubt that an eye which is already myopic will be more liable than an emmetropic eye to be attacked by it, and it will probably suffer in proportion to the degree of its myopia.

Astigmatism.—So far we have been considering the refraction that takes place at surfaces which have a symmetrical curvature, that is, surfaces which are formed by the revolution of a curved line about its centre, and therefore have the same curvature in all meridians. Rays coming from a point, and being refracted at such a surface, are again focussed in a point. We have now to consider refraction at a surface whose meridians have an unequal curvature, and therefore an unequal refractive power. Rays refracted by such a surface are not again brought to a focus in a point; such a surface is therefore said to be astigmatic (*α* privative; *στίγμα*, a point).

A familiar example of an astigmatic surface is the bowl of a spoon. When each meridian has the same curvature throughout, and the meridians of greatest and least curvature are at right angles to each other, the astigmatism is said to be regular. The meridians of greatest and least refraction are called the "principal meridians."

Fig. 67 illustrates diagrammatically the refraction that takes place at a surface that is regularly astigmatic. $a\ c\ b\ d$ is a refracting surface, of which the horizontal diameter, $c\ d$, has a shorter radius of curvature than the vertical, $a\ b$. Let a diverging pencil of rays fall upon the surface from f, and let the conjugate focus of f be at f_1' for rays which pass through the horizontal meridian, and at f_2' for those which pass through the vertical. A section of the cone of rays from f between f and the refracting surface will be circular, since the rays diverge equally in all directions. After refraction, however, the form of the section will vary with its position. Thus between the refracting surface and f_1' the cone will diminish in all its diameters, but more rapidly in the horizontal than in the vertical; consequently the section will be an oval, gradually becoming narrower as f_1' is approached, until at f_1' it is indistinguishable from a vertical line. Between f_1' and f_2' the rays in the horizontal plane, having crossed, will again diverge, while those in the vertical plane will continue to converge; hence, as f_2' is approached, we get in succession an oval figure with a long vertical diameter, a circle, an oval with a long horizontal diameter, and finally at f_2' a horizontal line. It is seen, therefore, that the rays, instead of converging towards a line formed by an axial ray (as in spherical refraction), converge towards two planes, which coincide with the principal meridians of the refracting surface.

From what has been said, the following rule may be adduced, which will enable the reader to understand all the phenomena of astigmatism which will presently be considered:

When rays coming from a point are refracted at an astigmatic surface, a linear image of the point is formed at the focus of each principal meridian; and the direction of the linear image is at right angles to the meridian at whose focus it is formed.

Astigmatism in the eye may be produced by a faulty curvature of any of the refracting surfaces, but usually depends upon asymmetry of the cornea; indeed, the vertical meridian of the cornea in most eyes has a slightly shorter radius of curvature than the horizontal. The astigmatism is, however, seldom recognised unless it is sufficient to cause some impairment of vision.

The degree of astigmatism is the difference between the refraction of the principal meridians. Thus if the vertical meridian were hypermetropic and corrected by + 1 D, while the horizontal required + 4 D, the degree of astigmatism would be 3 D. If the vertical required − 1 D and the horizontal + 3 D, there would be 4 dioptres of astigmatism; and so on.

Varieties of astigmatism.—It is usual to classify astigmatism according to the refraction of the principal meridians, thus:

Variety of Astigmatism.	Refraction of Principal Meridians.	Position of the Retina.
1. Simple hypermetropic	Emmetropic Hypermetropic	At the principal focus of one principal meridian.
2. Simple myopic	Emmetropic Myopic	
3. Compound hypermetropic	Both hypermetropic	In front of the focus of both meridians.
4. Compound myopic	Both myopic	Beyond the focus of both meridians.
5. Mixed	Hypermetropic Myopic	Between the foci of the principal meridians.

Every variety of regular astigmatism can be reduced to the simple form by correcting one of the principal meridians by means of a spherical lens.

From the rule given above, it will follow that the image of a luminous point on the retina of an eye with simple astigmatism will be a line at right angles to the emmetropic meridian. The reader will do well to impress this upon his memory by the following experiment: In front of the eye place a cylindrical lens with its *axis* (plane meridian) horizontal; the horizontal meridian of the eye remains unaltered, and is therefore emmetropic, but the vertical will be rendered myopic. Now let a point of light be looked at (a pin-hole aperture in front of a lamp answers the purpose well); this will appear not as a point, but as a vertical line, *i.e.* a line at right angles to the emmetropic meridian.

If now a line be looked at, it will only be clearly seen when its direction is at right angles to the emmetropic meridian, for every point on the line forms a minute linear image on the retina having that direction; when the direction of these images coincides with that of the line, they form a line by their overlapping; when, on the other hand, they have any other direction, and especially when they are at right angles to the line, the latter will appear widened out and blurred. (*See* Fig. 68.) This is better seen if several parallel lines separated by small narrow spaces be looked at; the latter then become completely obliterated.

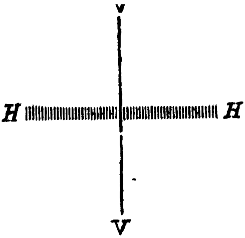

Fig. 68.

Hence we get this rule: *An eye with simple astigmatism can only see clearly lines that are at right angles to its emmetropic meridian.*

Applying the same laws to rays coming from any point on the retina, it will be seen that in astigmatism a linear image of the point will be formed at the far-point of each principal meridian, and that the direction of the image will be at right angles to the meridian at whose focus it is formed. When the meridian is emmetropic, the far-point being at infinity, no image would be formed: in the case of a hypermetropic meridian, the image would be virtual and behind the eye; in the case of a myopic meridian, it would be real and in front of the eye.

Cylindrical lenses.—A cylindrical lens is one whose surface forms part of the surface of a cylinder (Fig. 69); the meridian that is parallel to the axis of the cylinder is plane, the one that is at right angles to this will be the most curved, and the others will have an intermediate curvature. A lens whose surface forms part of the external surface of a cylinder is a convex cylindrical lens; one whose surface forms part of the internal surface of a hollow cylinder is a concave cylindrical lens. The direction of the plane meridian, or axis of the cylinder, is usually indicated by two marks upon the lens. A cylindrical lens is numbered according to the refraction of its most refracting meridian.

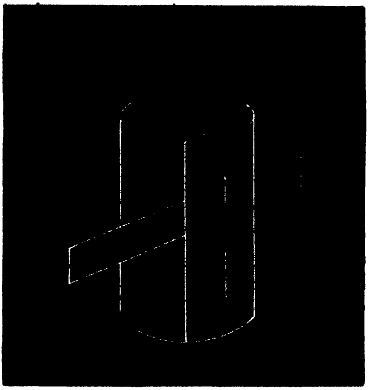

Fig. 69.—Diagram of a Convex Cylindrical Lens.

Rays falling upon such a lens are not refracted towards a line or axis of the lens, as in a spherical lens, but towards a plane, that of the axis of the cylinder. Hence the image of a point formed by such a lens will be a line having the same direction as the axis of the cylinder, and it will be formed at the focus of the most refracting meridian.

Tests for ametropia.—There are many methods of diagnosing the presence of ametropia and of estimating its degree. These may be classified under two heads: the *subjective*, which depend upon the patient's vision and the changes made in it by trial lenses, or by altering the distance of the test object; and the *objective*, in which the diagnosis rests upon what the surgeon sees in the patient's eye. The former are concerned with the rays which enter the patient's eye, the latter with the rays that leave it from the retina.

Trial lenses.—A case of trial lenses should consist of pairs of convex and concave spherical lenses from 0·5 D to 20 D, the weaker lenses having an interval of 0·50 D between them, and the stronger ones an interval of 1 D; it should also contain a set of cylindrical lenses up to 6 D, a set of prisms, a stenopaic slit, an opaque disc of the same size as the lenses, and an adjustable trial frame.

The test-types are placed at a distance of six metres, and the vision of each eye is tested separately, and the result noted in the manner shown on page 39.

I. If the *vision is normal* ($V = \frac{6}{6}$) myopia and astigmatism are excluded, and the eye is *hypermetropic* or *emmetropic* (I. in the Table on page 421). The near vision is tested with Jaeger's or Snellen's test-types, and the near-point (p.p. = punctum proximum) found; if this is farther away than it should be at the patient's age (*see* table on page 403), a suspicion of hypermetropia would be aroused; on the other hand, the fact of the patient reading at the normal distance does not exclude hypermetropia, as accurate focussing is not required in order to read brilliant type when held sufficiently close to give a large retinal image. A more accurate estimate of the position of the near-point can be obtained by using a smaller test object, such as fine parallel threads. The near vision is noted, giving the type read and the near-point; thus:

$$V\ \tfrac{6}{6} = \text{and } 0{\cdot}3\ \text{Sn.,}^{*}\ 20\ \text{cm.} = \text{p.p.}$$

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* Sn indicates Snellen's reading types.

SCHEME OF TESTING WITH TRIAL LENSES.

I. V NORMAL.	1. V not worse with convex lens . . .			= Hypermetropia.
	2. V worse with convex lens.	Atropine.	*a.* Remains normal.	= Emmetropia.
			b. Rendered subnormal.	= Hypermetropia.
II. V. SUBNORMAL.	1. V improved by convex lens.	*a.* Rendered normal.		= Hypermetropia.
		b. Subnormal.		= Comp. H. astig.
	2. V not improved by convex lens.	*a.* Improved by concave.	a^1. Rendered normal.	= Myopia.
			a^2. Subnormal.	= Comp. M. astig.
		b. Not improved by concave.		= Astig. simple or mixed.

The effect of weak convex lenses upon distant vision is now ascertained. If *a convex lens does not impair vision* (I. 1), there is a degree of hypermetropia present at least equal to the lens employed; for had the eye been emmetropic, that is, had the parallel rays been focussed on the retina when the accommodation was relaxed, even the weakest convex lens would have brought them to a focus sooner, and therefore have impaired vision. Evidently, therefore, if vision is as good with a convex lens as without it, the accommodation must have been used to focus the parallel rays when the lens was not used; in other words, the eye must be hypermetropic. The strongest lens is found which gives the best result, and the hypermetropia which is thus revealed is said to be manifest (Hm.), and the result of the test may be noted as in the following example:

$$V = \frac{6}{6} \text{ and } 0{\cdot}3 \text{ Sn. } (20 \text{ cm. p.p.}) + 1 \text{ D} = \text{Hm.}$$

A hypermetrope, having always been in the habit of accommodating in order to see clearly, does so instinctively and involuntarily; hence he cannot always relax his ciliary muscle fully, and must be coaxed to do so by very gradually increasing the strength of the lens used. But when the strongest glass has been found with which vision is still normal, we have no guarantee that some accommodation is not still being used; in other words, that some hypermetropia is not still *latent.* This is especially likely to be the case in young persons in whom the accommodation is strong. In such the total amount of hypermetropia can only be discovered by paralysing the ciliary muscle with a mydriatic. The points that should determine whether any (and, if so, what) mydriatic should be employed will be considered later; but we will now suppose that in the example before us atropine has been used, that the vision is then much impaired, and that a stronger convex lens is needed to bring it back to normal. Carrying the previous example a step farther, we note the result thus:

$$\text{V} = \tfrac{6}{6} \text{ and } 0{\cdot}3 \text{ Sn. } (20 \text{ cm. p.p.}) + 1{\cdot}0 \text{ D} = \text{Hm.}$$
$$\text{Atrop. V} = \tfrac{6}{18} + 4 \text{ D} = \tfrac{6}{6}.$$

In this instance the total H. is 4 D, and as only 1 D was manifest, 3 D were latent.

Vision is normal, and is *rendered worse by the weakest convex lens* (I. 2); there is no manifest hypermetropia, but there may be some latent. In persons over thirty this is improbable; in younger persons a mydriatic must be used, if the symptoms render it probable that H. is present.

If, when the accommodation is completely paralysed, distant vision is still normal, the eye must be emmetropic (I. 2 *a*).

If, on the other hand, the mydriatic impairs the previously normal vision (I. 2 *b*), it proves that the rays were only focussed on the retina before by the aid of the accommodation, and that the eye is therefore hypermetropic. A convex lens that restores normal vision indicates the amount of hypermetropia.

II. *Distant vision is sub-normal;* emmetropia is excluded;* the case may be one of hypermetropia, myopia, or astigmatism.

Vision is improved by convex lenses (II. 1); hypermetropia is present. The strength of the glass is gradually increased till the strongest one is found which gives the best vision attainable; this represents the amount of manifest hypermetropia.

Example: $V = \frac{6}{12} + 1{\cdot}5\ D = \frac{6}{6}$.

If, as in this instance, vision is rendered normal by a convex lens (II. 1 *a*), the case is one of hypermetropia only. If vision, though improved, is not rendered normal (II. 1 *b*), astigmatism is present, if the defect is due to ametropia.

In order to ascertain whether astigmatism is really present, the patient's power of seeing lines running in different directions is tested while he wears the lens which corrects his manifest hypermetropia. This can be done by using a fan of radiating lines, or, better, by means of Carter's astigmatic clock (Fig. 70), in which three parallel lines revolve round their centre. If the lines are seen equally well in all directions, astigmatism is excluded; if they are seen better in one direction

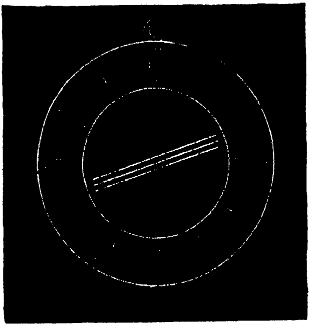

Fig. 70.—Carter's Astigmatic Clock.

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* Here, as throughout this chapter, it is assumed that the defect is due to an error of refraction.

than in the other, astigmatism is present. The method of ascertaining its degree will be considered presently.

Distant vision is subnormal, and *not improved by convex lenses* (II. 2); emmetropia and hypermetropia are excluded, and the case is one of myopia or astigmatism.

The near vision is tested; it is found that 0·3 Sn. can be read nearer than the distance of the near-point proper to the patient's age; myopia is almost certainly present. It will be found also that the greatest distance at which the patient can read is less than normal. The inability to read No. 0·3 Sn. at a distance of twenty-four inches might merely indicate a lowered acuity of vision, but in that case larger type would be read; the fact that it cannot, indicates that the limitation of vision is that of distance, and is independent of the size of the retinal image.

The greatest distance at which 0·3 Sn. can be read is generally taken as the far-point of the myopic eye, and this method of measuring the distance of the far-point is sufficiently accurate for practical purposes, although in high degrees of myopia, owing to the large visual angle under which the letters are seen, smaller test-objects would give a more accurate result.

The myopia will be corrected by a concave lens whose focus coincides with the far-point (Fig. 66), for such a lens will give to parallel rays the same amount of divergence as if they came from that point, and will therefore enable them to be focussed on the retina without any accommodation being employed. It is therefore practically convenient to measure the far-point from the position that the correcting lens would occupy in front of the eye.

Example: $V = \frac{6}{60}$ *and* 0·3 Sn. 8 ins. = p.r.*

If the case is one of simple myopia, a lens of 8 ins.

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* p.r. = *punctum remotissimum.*

focus (5 D) will render distant vision normal (II. 2 a^1). In ascertaining which lens corrects the myopia, it is important to give the weakest that gives the best result; a lens that is stronger than necessary will make the rays diverge from some nearer point than the "far-point" of the eye, when the vision may still be good, but only by the accommodation being called into play.

If *a concave lens improves the distant vision* up to a certain point, but *not to the normal standard* (II. 2 a^2), either astigmatism is present or the visual acuity is lowered. If with the lens which gives the best vision, lines running in one direction are seen better than others, astigmatism is present.

In myopia over 8 D some lowering of the visual acuity is usually present, owing to the changes in the fundus described on page 410.

When neither convex nor concave lenses improve vision (II. 2 *b*), astigmatism simple or mixed may be suspected to be present. When spherical lenses improve vision to some extent, but do not render it normal, compound astigmatism may be suspected; the diagnosis is confirmed if some lines are seen better than others.

If lines running in one direction are seen with perfect clearness, and spherical lenses do not improve vision, the case is one of *simple astigmatism,* and the meridian that is emmetropic is the one at right angles to the line seen. (*See* rule, page 418.)

If a stenopaic slit be placed in front of the eye so that only the emmetropic meridian is used, vision will be normal. With the slit in any other position, it will be subnormal, and will of course be worst when the slit is at right angles to the emmetropic meridian.

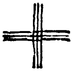
The nature and amount of the astigmatism can be ascertained in either of the two following ways:

(*a*) Rotate the line through 90° so that it is in the position in which it appears most bleared, and then add spherical lenses until it is seen as clearly as it was in its original position. The lens used will indicate the degree of astigmatism. For example : vertical lines are seen clearly, but to render horizontal lines distinct -2 D is required ; the case is one of simple myopic astigmatism, the horizontal meridian being emmetropic, and the vertical having 2 D of myopia.

(*b*) The second method is far preferable, but it necessitates the use of cylindrical lenses. The emmetropic meridian having been found in the manner described, cylindrical lenses with their axes parallel to this meridian are added until all the lines are equally clear; this lens should render the vision normal.

For example, horizontal lines are seen clearly; the vertical meridian is therefore emmetropic. Cylinders are added with their axes vertical, and it is found that $+1{\cdot}5$ D renders vertical and horizontal lines equally clear. The result may conveniently be expressed thus :

$$V = \tfrac{6}{12} \text{ and } \underline{\underline{\textit{best}}} \quad + \; 1{\cdot}5 \text{ cyl. } \textit{ax.} \; \Big| \; V = \tfrac{6}{6} \text{ and}$$



Other varieties of astigmatism are equally easy to manage if it be borne in mind that by the addition of a spherical lens which corrects one of the principal meridians they can all be converted into simple astigmatism.

For example :

$$V = \tfrac{6}{24} \quad - \; 1{\cdot}5 \text{ D} = \tfrac{6}{12} \text{ and } \underline{\underline{\textit{best.}}}$$

The presumption is that $-1{\cdot}5$ sp. corrects the vertical meridian. This can be confirmed or corrected with the stenopaic slit. The case is thus reduced to simple astigmatism, and all that remains is to remove the slit and to add cylindrical lenses with their axes vertical, until the lines are seen equally well in both directions.

When the astigmatism is mixed, spherical lenses are employed till the lines are seen clearly in one direction; the exact correction of the meridian at right angles to this is then found with the aid of the stenopaic slit, the case being thus reduced to simple astigmatism. The correction is found, as in the preceding example, by adding cylindrical lenses with their axes in the direction of the corrected meridian.

The refraction of each principal meridian having been found, the correction may be given in either of the following ways: (*a*) The myopic meridian may be corrected with a spherical lens, and a + cylindrical lens be added; (*b*) the hypermetropic meridian may be corrected and a concave cylinder used; (*c*) the two meridians may be corrected by cylinders of opposite signs, their axes at right angles to each other. The latter will, as a rule, be found the least convenient.

The rule for correcting astigmatism may therefore be summed up thus:

If one of the principal meridians is not already emmetropic, render it so with a spherical lens; then add a cylindrical lens having its axis in the direction of the corrected meridian.

The principles upon which the above tests depend have been utilised in a variety of instruments, called optometers. The majority of these are simply mechanical contrivances, often of very ingenious construction, for facilitating the changing of the lenses. Tweedy's optometer differs from these in that with it the diagnosis chiefly rests upon alterations in the distance of the test object, and not upon the lens that is necessary to render it clear. The test object is a card on which is a series of fine radiating lines. This slides along a graduated bar, at one end of which the patient places his eye, and, if he is not already myopic to such an extent that the farther extremity of the bar lies beyond his far-point, he is rendered so by a convex lens placed in front of his eye in a clip provided for the purpose. The card is now taken to the farther end of the bar, so that none of the lines are clearly seen, and is then gradually approximated. If the eye is emmetropic, all the lines will come into focus as soon as the position of the card coincides with the focus of the lens, for the rays will then be parallel. If the eye is hypermetropic, they will be seen sooner, *i.e.* while the rays after passing through the lens are still convergent; and if myopic, later, *i.e.* not till the rays are divergent. Allowance being made for the strength of the lens, the graduations on the bar indicate the degree of ametropia. If there is astigmatism, one line will come into view before the others; from the position of the card at this moment the refraction of the meridian at right angles to the line seen can be calculated. Cylinders may then be added until all the lines are equal; or the refraction of the other principal meridian can be calculated in the same manner.

Practically, the difficulty with this instrument is that patients often find it difficult to say when the line becomes clear; no doubt, however, a surgeon who used the instrument constantly would learn when it is safe to rely upon the patient's statement.

Among objective tests for refraction the use of the ophthalmoscope ranks foremost. It may be employed for this purpose in several ways.

Direct ophthalmoscopic examination.—Since the rays from any point on the retina of the emmetropic eye are parallel on leaving the eye (Figs. 64 and 71), they are focussed upon the retina of an emmetropic observer without the latter using any accommodation; hence he will obtain a clear view of the fundus, while the weakest convex lens will blur the image, since it will cause the emergent rays to converge, and he cannot focus convergent rays.

In hypermetropia the rays as they leave the eye are divergent (Fig. 65); hence they can only be focussed upon the observer's retina if he uses his accommodation. Most persons, however, accommodate instinctively and unconsciously, so that the fundus, except in extreme hypermetropia, is seen easily. If now a convex lens be placed behind the ophthalmoscope, the rays are rendered less divergent or parallel, and the fundus is still seen if the observer relax his accommodation. If the observer has the power of completely relaxing his accommodation, the strength of the lens can be gradually increased until one is reached which renders the rays parallel, *i.e.* which corrects the hypermetropia. A stronger lens than this will render the rays convergent, and therefore blur the image.

If, therefore, the fundus is seen clearly without any lens, and also with a convex lens, the eye is hypermetropic; the strongest lens with which the fundus can be seen is the measure of the hypermetropia.

In myopia the rays, as they leave the eye, are convergent (Figs. 66 and 73), and therefore cannot be focussed upon the retina of an emmetropic eye. Hence *a clear view of the fundus can only be obtained with a concave lens, and the weakest lens with which it can be seen is the measure of the myopia.*

In astigmatism lines (for example, blood-vessels or the edge of the disc) running in some directions will be visible under different conditions from others. For instance, taking the case of simple astigmatism, and supposing the horizontal meridian to be emmetropic, the retina of the emmetropic observer will be at the focus of rays coming out in the horizontal meridian; therefore by the rule given on page 416, every point of the patient's fundus will be seen as a small vertical line; hence vertical blood-vessels and the lateral margins of the optic disc will be clearly seen, while all other lines will be more or less blurred. In order to see the horizontal vessels and the upper and lower edges of the disc, it will be necessary to use a convex or concave lens, according as the ametropic principal meridian is hypermetropic or myopic. When both principal meridians have the same kind of ametropia, but in a different degree (compound astigmatism), the refraction is reduced to simple astigmatism by correcting the meridian which has the least ametropia by a spherical lens behind the ophthalmoscopic mirror. The correction required for this meridian having been noted, the surgeon sees what additional strength is required for the meridian at right angles to it. In mixed astigmatism the vessels which are at right angles to the myopic meridian will only be visible with a concave lens, while those at right angles to the hypermetropic meridian will be visible with a convex lens. When the astigmatism is at all considerable, the disc will appear oval, its long diameter corresponding with the meridian of greatest refraction. Some ophthalmoscopes are provided with cylindrical lenses, when the above proceeding is somewhat simplified.

There is no doubt that this test, in the hands of those who have thoroughly mastered it, is one of the most valuable that we possess, but for several reasons it is an exceedingly difficult one to learn. The chief difficulty lies in the fact that the instinctive desire for distinct vision, and the habit of accommodating when examining near objects, causes most persons at first to accommodate involuntarily and unconsciously; some, even after many attempts, are unable to relax the accommodation at all in response to the will; while many more can only relax it partially. A partial relaxation would be sufficient were the remaining accommodation a constant factor, but with most it varies very much from day to day, and even at different times in the same day.

Another difficulty in astigmatism is due to the fact that there are few or no vessels near the macula, and it is the refraction at that part, and not that at the optic disc, which is required; and since the vessels do not radiate regularly it is not always possible to find one running in the required course. In the higher degrees of ametropia a source of error is introduced if there is any slight variation in the distance at which the ophthalmoscope is held; when the latter is too far away, hypermetropia is under-, and myopia over-estimated.

Mr. Tempest Anderson has devised an ingenious addition to the ophthalmoscope, by means of which shadows of fine radiating lines are thrown upon the patient's fundus, and these are used as the test lines instead of the vessels. The instrument is devised and constructed with much ingenuity; but the fact that it is expensive and rather cumbersome (and possibly also the institution of the "shadow test") has prevented its general adoption.

To recapitulate: *If the details of the fundus can be seen without any lens, and not with a + lens, the eye is emmetropic.*

If they can be seen with a + lens it is hypermetropic; the highest lens with which they can be seen is the measure of the hypermetropia.

If the fundus can only be seen with a concave lens the eye is myopic; the weakest lens required is the measure of the myopia.

If vessels running in different directions are visible with different lenses, astigmatism is present.

Indirect ophthalmoscopic examination.—

In emmetropia the image is always formed at the principal focus of the object lens, and is therefore always of the same size, whatever may be the position of the latter. In hypermetropia the image is larger than in emmetropia when the lens is held close to the eye, and diminishes as it is withdrawn. In myopia it is smaller than in emmetropia when the lens is close to the eye, and enlarges as it is withdrawn. When the lens occupies an intermediate position, so that its principal focus coincides with the anterior focal point of the eye, the image is of the same size whatever the refraction.

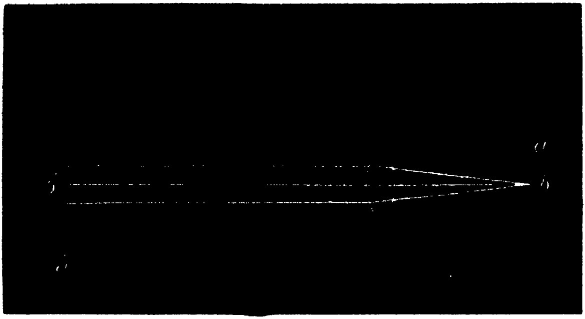


Fig. 71.—Emergent Rays in Emmetropia.

Astigmatism can be diagnosed by the changes in the shape of the disc that take place as the lens is withdrawn. In the emmetropic meridian the disc remains of the same diameter, in a myopic meridian it increases, and in a hypermetropic it diminishes.

When the lens is held close to the eye the diameter of the disc is greatest in the meridian of least refraction (the reverse of the appearance seen by the direct method); as it is withdrawn it becomes circular, and then again oval, the greatest diameter coinciding with the meridian of greatest refraction.

This test, although useful as a qualitative test, is not of much value for measuring the degree of ametropia.

For an explanation of these phenomena the reader is referred to an article by M. Parent.*

Fundus image test.—In this test the fundus is illumined by throwing the light into the pupil from a mirror held at a distance of two feet or more. In emmetropia the pupil will appear of a bright red colour, but no details of the fundus will be visible; for in order that any object, however small, may be visible, it is necessary that its several points should have corresponding foci on the retina. But a glance at Fig. 71 will show that in emmetropia the observer, if at a distance from the eye, can only receive rays from one point of the fundus at a time, namely, from that which lies on the axis along which he is looking, for rays from any other point will form a pencil of rays parallel to the axis on which it is situated; and as the axial rays from any two points on the

Fig. 72.—Formation of virtual Erect Image of Fundus in Hypermetropia.

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* *Recueil d'Oph.*, p. 544; 1881.

retina, however close together they may be, are constantly diverging from each other, they will be widely separated by the time they reach the eye.

In hypermetropia the case is different; the rays from two points (*a* and *b*, Fig. 72) are now divergent; hence they form fan-like pencils, which are constantly increasing in size, and may overlap each other. The observer's eye will then receive rays from both points, and will see virtual images of both at *a′* and *b′*, where the rays would meet if prolonged backwards.

Fig. 73.—Formation of real Inverted Image in Myopia.

Hence a *virtual* erect image of *a* and *b* and of the portion of the fundus between them is seen. This image, being situated behind the eye, will appear to move with the observer when the latter moves his head in different directions, owing to the effect of parallax.

In myopia the rays, being convergent, come to a focus at the far-point, and here a real inverted image is formed, which is seen as if it were an actual object; since it is nearer to the observer than the eye, the effect of parallax is to make it move in the opposite direction to the observer's head (Fig. 73).

In astigmatism an image (virtual in H, real in M) of a line whose direction is at right angles to one of the principal meridians will be formed at the "far-point" for that meridian. For example, in a case of mixed astigmatism, with vertical myopia and horizontal hypermetropia, a real image of the horizontal vessels will be formed at the focus of the vertical meridian, and this, when the observer moves his head up and down, will move in the opposite direction; while at the far-point of the horizontal meridian (which is behind the eye) a virtual image of vertical vessels will be seen, which will move in the same direction as the observer's head. In the case of simple astigmatism, only those vessels will be visible at a distance which are at right angles to the ametropic principal meridian.

This test, again, is little used as a quantitative one, but the reader is advised thoroughly to master the theory of it, or he will be unable to understand the *rationale* of the following test.

Shadow test.—One of the most useful methods of estimating refraction is that which goes by the names of "pupilloscopy," "koroscopy," "keratoscopy," or "retinoscopy," all of which terms are open to objection, either because they are incorrect, or because they would apply with equal fitness to many other tests. A better name would be "shadow test" or its equivalent.

When light from a lamp flame is reflected into an eye from a mirror held at a distance of a little over three feet, it is concentrated by the refracting system of the eye, so that only a very small portion of the fundus is illuminated. If the eye is emmetropic, the portion of the fundus which is visible to an observer whose eye is placed behind the sight-hole of the mirror is a mere point, and the area which is visible in ametropia is proportionate to the degree of ametropia. (*See* preceding test.) When the mirror is rotated about one of its diameters, the position of the light upon the fundus is changed; but if the sight-hole remain in the same position, the portion of the fundus which is visible remains the same. Accordingly the illumination of the portion which is seen (the reflex from which occupies the pupil) will vary with the rotation of the mirror, and in some positions of the latter, only part of the visible area will be illumined, and accordingly part of the pupil will appear to be occupied by a "shadow." The test depends on the observation of the direction and rate of movement of this "shadow."

Fig. 74.—Shadow Test with Concave Mirror.

The shadow test may be practised either with a concave or a plane mirror. A concave mirror is more commonly employed (Fig. 74); its focus should not be less than 20 cm., and one with a longer focus answers still better. The rays from the lamp, falling upon such a mirror, are brought to a focus a little nearer to the patient than the principal focus of the mirror, and here an inverted aërial image of the flame (l_1) will be formed. If the patient's eye is adapted for the distance at which the aërial image lies, an image of this again (l'_1) will be formed on its fundus; in every other state of refraction the illuminated patch on the fundus will be a circular or nearly circular diffusion figure. If the mirror be now rotated in any direction, say, downwards (to the position shown by the dotted line, M_2), the position of the aërial image will move in the same direction (from l_1 to l_2), and, since the relative positions of external objects are reversed on the fundus, the illuminated area on the latter will move in the reverse direction to that of the rotation of the mirror (from l'_1 to l'_2); and it is evident that this will be the case, whatever the refraction of the eye may be.

Fig. 75.—Shadow Test with Plane Mirror.

With a plane mirror the effect will be the reverse of that just described. No real aërial image of the flame is now formed, but when the mirror is in its first position (M_1), its virtual image lies behind the mirror in the direction of l_1 (Fig. 75) and the retinal image at l'_1. When the mirror is rotated downwards (to M_2) the virtual image is moved upwards, so that it lies in the direction of l_2; accordingly, the illuminated area on the fundus moves downwards (from l'_1 to l'_2).

Therefore, in all states of refraction, with a concave mirror the light upon the fundus moves in the reverse direction to that of the rotation of the mirror, while *with a plane mirror it moves in the same direction as the mirror.*

Although the *actual* direction of movement of the light upon the fundus is the same in all states of refraction, its *apparent* movement, to an observer behind the sight-hole of the mirror, is different in hypermetropia and in myopia.

In hypermetropia an erect image of the fundus is seen, and the apparent movement is therefore the *same* as the actual. But in myopia the image which is seen is inverted; accordingly the apparent movement is the *reverse* of the actual.

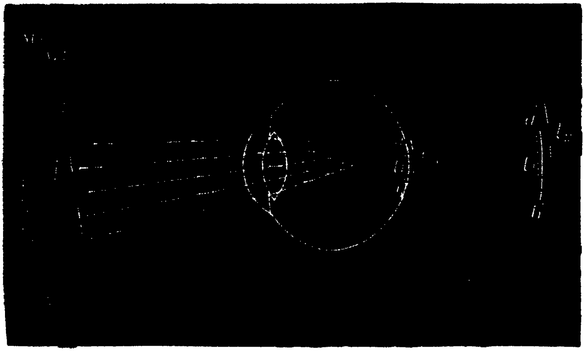

Fig. 76.—Shadow Test in Hypermetropia.

In emmetropia, since the area which is visible is smaller than that which is illuminated, the latter can move to some extent without the visible area losing the illumination. On the other hand, when the movement exceeds this limit, the illumination is rapidly lost over the whole visible area.

The preceding statements will be rendered more intelligible by a consideration of the annexed diagrams:

Fig. 76 represents a hypermetropic eye. At the distance at which the observer is placed, it is supposed that the portion of fundus visible is *a b*, and of this he sees an erect virtual image *a′ b′* (the portion actually visible has been exaggerated for the sake of clearness). For the sake of simplicity, we will assume that when the concave mirror is in the position M_1 (the distance of the mirror is not shown) the illuminated area l_1 coincides with *a b*; in this case the whole of the image *a′ b′* will be illuminated, and the whole pupil appear occupied by a red reflex. Now let the mirror be rotated to M_2, the position of the illuminated area and of its image will shift to l_2 and l'_2; consequently the part of the image nearest to *b′* will be in shade, and the lower part of the pupil be occupied by a shadow, whose height will vary with the rotation of the mirror (Fig. 77), and which will therefore move in the *opposite* direction to the rotation of the mirror.

Fig. 77.—Shadow Test, Appearance of Pupil.

Fig. 78 represents a myopic eye, of the fundus of which a portion *a b* is visible to the observer, and of this he sees a real inverted image *b′ a′*. As before, we will suppose that in the first position of the mirror M_1 the illuminated area l_1 and its image l'_1 coincide respectively with *a b*, and *b′ a′*; then, when the mirror is rotated to M_2, l_1 shifts to l_2, leaving the part of the visible area nearest to *b* in shade; consequently the part of the image nearest to *b′* will be in shade, and the upper part of the pupil (Fig. 79) be occupied by a shadow, which will move in the *same* direction as the rotation of the mirror.

A shadow which moves in the same direction as a concave mirror always indicates myopia; but since this direction of the movement depends on the fact that the view which is obtained of the fundus is *inverted*, it will only be seen when the observer is beyond the far-point of the eye. For this reason

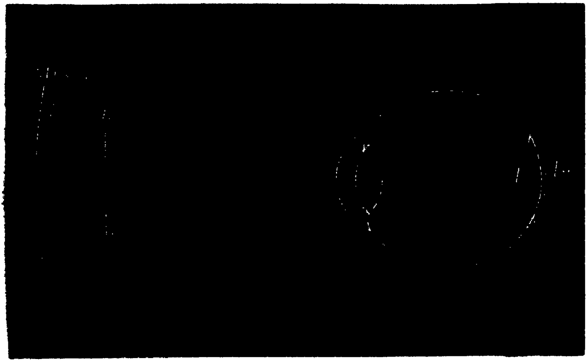

Fig. 78.—Shadow Test in Myopia.

it is difficult by this test to recognise a degree of myopia which is much less than 1 D, for if the distance is increased much beyond 1·25 metres, the illumination becomes very feeble; if, however, a plane mirror be used, the observer may be as much as two metres away, and still obtain sufficient illumination. For this reason some prefer to use a plane mirror.

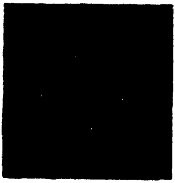

Fig. 79.—Shadow Test, Appearance of Pupil.

In emmetropia the mirror can be rotated to some extent before the shadow is seen; when it does appear, its margin is indistinct, its movement is in the reverse direction to that of a concave mirror, and is rapid. The movement of the shadow is slow and the reflex dull, in proportion as the refraction departs from the emmetropic standard.

In order to estimate the amount of an error of refraction by the shadow test, the trial frame is placed upon the face, and, the direction of the movement of the shadow having been noted, lenses of different strength are placed in the frame until the emmetropic appearance is produced. Some gradually increase the strength of the lens until the original direction of the shadow is reversed; the glass which does this, of course, over-corrects the error. Whatever plan is adopted, it will be found that hypermetropia is always slightly over-, and myopia slightly under-estimated. The amount of the error varies with different observers, but after a little practice is constant for the same observer, and ceases to be of any practical importance. With the plane mirror a more accurate result can be obtained; but the inconvenience of standing at a great distance, and being unable rapidly to change the lenses, more than counterbalances any advantage on this score.

The chief value of this test consists in the rapidity and accuracy with which it enables astigmatism to be diagnosed and estimated.

The refraction of any given meridian is indicated by the apparent movement of the shadow in that meridian. For instance, if on rotating the mirror on its vertical meridian, so that the movement of the light is transverse, the emmetropic appearance is seen, while on rotating it on its horizontal meridian a shadow having a horizontal edge is seen moving up and down in the same direction as the mirror, the case is one of simple myopic astigmatism, the vertical being the most myopic meridian, and the horizontal being emmetropic.

When there is ametropia without astigmatism, every part of the edge of the shadow (*i.e.* of the line of separation between the illuminated and the unilluminated portions of the fundus) is seen with the same definition; but this is not the case when astigmatism is present. Thus, in the above example of simple myopic astigmatism of the rays from any point on the fundus, some will come to a focus at the far-point of the myopic (vertical) meridian, and here will be formed, not a true image of the point, but a horizontal linear image of it. Accordingly the horizontal edges of the shadow will be the only ones which will be clearly defined (Fig. 80), and these, of course, can only come into view when the mirror is sufficiently rotated upon its horizontal axis.

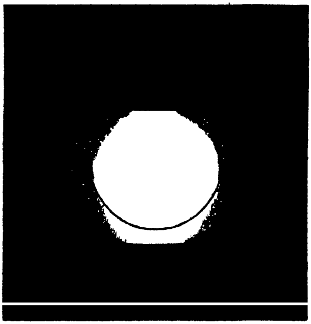

Fig. 80.—Illumination on Fundus in Astigmatism.

The continuous line marks the limit of the portion seen. The shaded outline shows the limit of the patch of light, which has been shifted downwards.

When the principal meridians of the eye do not exactly coincide with the axes on which the mirror is rotated, this will be indicated by a corresponding obliquity of the edge of the shadow, and of the direction of its apparent movement, these corresponding, not with the axes of rotation, but with the principal meridians.

The real movement of the shadow upon the fundus is always at right angles to the axis upon which the mirror is rotated. The only movement, however, which is apparent is that portion of it which takes place along a line at right angles to the edge of the shadow. This can easily be seen by the simple experiment, suggested by Dr. Charnley,* of passing across an aperture in a horizontal direction a card with its edge held obliquely, when the apparent

* Ophthalmic Hospital Reports, vol. x. pp. 3, 344.

movement will be oblique and at right angles to its edge (Fig. 81). If, therefore, in the above case the principal meridians, instead of being vertical and horizontal, were a little oblique, the edge of the shadow which would come into view when the mirror was rotated on its horizontal axis would have a corresponding obliquity; and although its real movement would still be in a vertical direction, it would appear to be at right angles to its edge. The greatest amount of movement will, of course, be seen when the axis of rotation of the mirror coincides with the principal meridian.

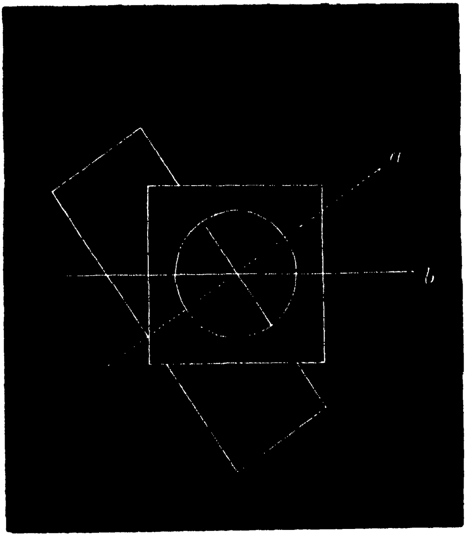

Fig. 81.—*a*, Apparent direction of movement; *b*, real direction.

The preceding statements will perhaps be rendered of more practical value by a few examples:

(1) There is a dull reflex, and a shadow which moves but little, and in the reverse direction to a concave mirror, in all meridians; the case is one of hypermetropia of high degree.

Convex lenses are now added, gradually increasing their strength; the reflex becomes brighter and the movement of the shadow more rapid (hypermetropia of low degree). The strength of the lenses being further increased, it is found that the movement of the shadow in the vertical meridian only appears when the mirror has been rotated through a considerable angle, and that then the brightness of the reflex is lost over the whole pupil almost instantaneously, although it can still be seen that the reflex leaves the pupil in the opposite direction to the rotation of the mirror. The lens used will approximately indicate the amount of hypermetropia in the vertical meridian (in reality, it will be a little less than this).

The lens last used being left in the trial frame, the mirror is now rotated on its vertical axis; a shadow moves across the pupil in the opposite direction, its edge being vertical. Astigmatism is present, the horizontal meridian being more hypermetropic than the vertical. The case, therefore, is one of compound hypermetropic astigmatism.

Convex cylindrical lenses may now be added, with their axes vertical, until the same appearance is produced in the horizontal as in the vertical meridian. The astigmatism is now corrected; it only remains to test the patient's vision, and see if it is improved by slightly reducing the strength of the spherical lens.

(2) On rotating a concave mirror on its horizontal axis, a shadow is seen moving in the same direction as the mirror; while on rotating on the vertical axis, it moves in the reverse direction, the edge of the shadow in each case being slightly oblique. The case is one of mixed astigmatism, the (approximately) vertical

meridian being myopic, and the meridian at right angles to it hypermetropic. Spherical lenses are now used until one of the principal meridians is rendered emmetropic, and cylinders are then added, with their axes parallel to the edge of the remaining shadow, until the meridians are rendered equal. When, as in this instance, the principal meridians are oblique, it is better to rotate the mirror about meridians of corresponding obliquity.

General considerations.—In children it is seldom safe to attempt to estimate the refraction without first paralysing the accommodation with a mydriatic.

In the case of adolescents, and adults under thirty, this is, as a rule, unnecessary in cases of myopia, but desirable in hypermetropia and astigmatism. In patients over thirty a mydriatic is only necessary in astigmatism, or when there is any reason to suspect spasm of the ciliary muscle, or when there is great want of control over the muscle, as shown by variations in the answers given in subjective tests.

The mydriatic most generally employed is a solution of sulphate of atropia (Formula 5 or 6). It should be used three times a day for three or four days, or for longer when there is spasm of accommodation. The effect of the atropine upon the accommodation does not pass off for a week or ten days after the last application, so that its use is extremely inconvenient to those who are following any occupation. In the case of children and in some other cases the rest that is thus enforced is beneficial; in other cases a solution of homatropine hydrobromate (Formula 9) may be substituted. If this is instilled every ten minutes for about an hour, full paralysis of the accommodation can usually be effected, from which complete recovery takes place in from twenty-four to thirty-six hours. Homatropine is probably less efficient than atropine in cases of spasm of the accommodation.

In testing the refraction it is generally best to commence with the trial lenses. When there is no astigmatism, and the patient is fairly intelligent, this will usually be found the quickest test. When by this test vision cannot be brought up to normal, the eye should be examined with focal illumination and with the ophthalmoscope, in order to ascertain whether there are any conditions to account for a lowered acuity of vision, or if there is any evidence of astigmatism. If the latter, an approximate idea of its amount and nature may be obtained by the direct method, and the shadow test be then proceeded with. The correction having been thus found, the distant vision should again be tested, and any slight alteration that improves the vision be made.

It is important not only that the glasses should have the proper focus, but that they should be so placed that each eye looks through the centre of the lens. By most persons any pair of spectacles that can be kept on the face is considered to fit, hence married women who are about five years younger than their husbands not unfrequently come in for the reversion of the latter's first pair of spectacles, and well-meaning district visitors present their *protégés* with the cast-off spectacles of their own relatives. If, however, the glasses are not properly centred, they act as prisms, and by modifying the amount of convergence required may cause considerable discomfort.

When the refraction has been measured, the question arises, what glasses are to be given to the patient, and under what circumstances are they to be worn? As regards distant vision, if full correction be given to a young hypermetrope he will generally be unable to see clearly with the glasses, owing to his inability entirely to relax his accommodation. Much, however, may be done in the latter respect by perseverance, and if half a dioptre be subtracted from the fully correcting glasses it will generally be found to be sufficient. A more logical proceeding is to correct all the manifest hypermetropia and a constant fraction (half) of the latent. Some prefer at first only to correct a small fraction of the ametropia, and to increase the strength of the glasses later. This is, however, usually quite unnecessary. In the case of an adult whose hypermetropia is under 3 D, and who has no symptoms in distant vision, glasses need not be given for this purpose. In the case of children it is better that the glasses should be worn constantly; otherwise they are laid aside and forgotten, and the abnormal muscular contraction that the patient is called upon to make increases the tendency to strabismus and ciliary spasm. Ordinary prudence would, however, suggest that schoolboys should remove their glasses before joining in a game of football, or any other pugnacious amusement.

Adults with hypermetropia over 3 D should be advised to wear glasses constantly.

In the case of adult myopes the patient will best consult his own convenience by wearing glasses constantly for distant objects. If they are not required for near objects also (*see* below), they should be set high, and the lower edge of the glass be cut nearly or quite straight, so that the patient can see under them. If the inconvenience of blurred vision is preferred to the supposed unsightliness of spectacles, double eye-glasses should be given for use when the patient thinks he requires them; the use of a single eye-glass should be discouraged when the power of binocular vision is present. Myopic children should certainly wear correcting glasses for distant vision for educational reasons. When, however, the myopia is of high degree, and is believed to be progressive, the case is exceptional, and will be considered below.

With regard to near vision, all hypermetropes and presbyopes must wear their glasses. When glasses are required both for distance and near vision, but of different foci, spectacles of double focus (Franklin's spectacles) are useful. In these the distance-glass is placed above, and the reading-glass below, the two being separated by a horizontal line, and it is essential to the patient's comfort that this should be placed sufficiently low to enable him to see the floor a few feet in front of him through the upper lenses, by making a very slight inclination of his head. It is better that the lower edges of the lower glasses should be tilted a little backwards. Such glasses are rather unsightly, but very convenient; the horizontal dividing line, being within the near-point, is of course quite invisible to the wearer.

As to glasses to be worn by myopes in near vision, considerable difference of opinion exists. An adult who has always been accustomed to use his eyes for near objects without glasses will seldom care to alter his habits; glasses which correct his ametropia would require him to make the same accommodative effort in looking at near objects as an emmetrope, and to this effort he has long been unaccustomed. Such patients, however, when their myopia is of rather high degree (over 6 D) not unfrequently require glasses to enable them to see comparatively near objects, which yet lie beyond their far-point (for instance, a page of music or a ledger). In many instances the distance-glasses may be worn for this purpose if the patient is under thirty and will persevere in their use. If, however, the diminution in the size of the images and the fatigue produced by the effort of accommodation render these uncomfortable even after a fair trial, or if the patient is over thirty, glasses may be given which enable him to see at the required distance without using any accommodation. To do this, all that is necessary is to add to the fully correcting glass a convex lens whose focal length is the required distance. For example, a myope of 10 D wishes to see at 20 ins. A lens of this focus is 2 D; hence he will require (−10+2=) −8 D. In young myopes the case is quite different; if the eyes are used upon near objects without glasses the child stoops over his book or work, a great effort of convergence is called for, and all the conditions are produced which tend to increase the myopia. (*See* page 408.) Hence the correcting glasses should be worn both for near and distant vision. It is, however, of importance that with the glasses a proper reading distance should be maintained, and this will often require constant supervision, and it may even be necessary to employ mechanical means, to prevent the child unduly approximating his eyes to his work. One of the best instruments for accomplishing this object is that contrived by the Breslau optician, Kallman; it consists of a light frame which rests against the patient's forehead and chin, and is fixed by a stem to the edge of the table * If, however, the parents are intelligent and painstaking, mechanical appliances are better dispensed with. When the myopia is of high degree, accompanied with atrophic changes in the choroid, and increasing, it is possible that the contraction of the ciliary muscle may tend to increase the choroidal changes, while the lowered visual acuity increases the tendency to hold objects too near. In such a case glasses may be given for constant wear about two dioptres weaker than the myopia, and eye-glasses of two dioptres be given to be added occasionally to the spectacles to increase the clearness of distant objects.

By those who believe that the contraction of the ciliary muscle is one of the main factors in increasing myopia, it is not considered safe to allow a myope to wear glasses for any distance at which he can see without them when his accommodation is in abeyance.* That full correction of myopia (the glasses being constantly worn) is not always injurious is the experience of many in this country who for years have adopted this practice, and this is confirmed by some important statistics recently published by Foerster.† As in most cases, the safe road lies between two extremes. In some cases of high myopia the ciliary muscle is either structurally defective or atrophied from want of use; in such the attempt to make it perform work for which it is incompetent will cause fatigue and congestion of the eyes, and will at any rate so far favour the development of the myopia that it renders the eyes less fitted to resist any injurious influences. On the other hand, he who never allows a myope to neutralise his defect robs his patients of the benefit of science, in order to gratify his own wish to be consistent to his favourite theory.

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* It is made by Messrs. Baker, 224, High Holborn.

When there is a difference in the refraction of the eyes (anisometropia), it is sometimes a little difficult to know how to deal with the case, and it is impossible to lay down hard-and-fast rules, as individual cases differ much; the following indications may, however, be helpful:

In children each eye should be given its proper correction. If this is done in adults, discomfort is frequently complained of, either because the images in the two eyes are of different sizes, and the patient is unable to fuse them; or because, owing to the great degree of ametropia in one eye, he has been accustomed to disregard its retinal images, and resents their being forced upon his attention. When the difference in refraction is only slight (less than 3 D), an attempt should be made to correct both eyes; but if discomfort is complained of, each eye should be furnished with the correction of the least ametropic. When there is great disparity between the eyes, it will usually be found that the patient has no binocular vision, and often that one eye is used for distant and the other for near vision; in such cases the eyes must be treated as distinct organs, and each be given the correction required for its own work.

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* Landolt, "Errors of Refraction and Accommodation." 1886.

† *Archiv of Ophthal.*, Dec., 1886.

In patients over forty allowance must be made, in ordering reading glasses, for the failing accommodation. Presbyopia has been defined as the condition in which, owing to the failure of accommodation from age, the near-point has receded to more than 8 ins. This will evidently occur sooner in hypermetropia, and later in myopia, than in emmetropia; indeed, in myopia of 5 D or more, in which the far-point lies within 8 ins., presbyopia can never come on.

A convenient practical rule is to add to the glass which renders the eyes emmetropic the presbyopic correction which at the patient's age an emmetrope would require. For instance, a hypermetrope of 2 D at the age of 50 would require $2 + 2 = 4$ D. A myope of 2 D of the same age would require no glass $(-2 + 2)$; at 60 he would want $-2 + 4 = +2$ D. Slight alterations may be made to suit individual peculiarities or particular kinds of work, but the above rule will usually be found to work well.

It is often the duty of the surgeon to advise young people or their parents as to the kind of occupation which it will be safe for them to follow. Where so much depends upon individual circumstances, it is of course only possible to lay down very general rules. Those who are the subjects of progressive myopia should be forbidden to follow any sedentary occupation that requires the eyes to be used much upon near objects, a warning that is the more necessary since such individuals are usually of studious habits, probably owing to their having to a great extent been debarred, by their infirmity, from outdoor sports during school life. They are unfitted for such occupations as bankers' clerks or accountants, since, in addition to the long desk hours, working at figures involves a great strain; but with their myopia corrected, the less severe cases may write for many hours a day under suitable conditions. In the higher degrees of progressive myopia the patients should be advised to use some of the many excellent type-writers. Unfortunately most outdoor occupations, which would otherwise be suitable for these patients, require the possession of good distant vision; and if they have to be carried on in all states of the weather, glasses cannot be worn without inconvenience. Moderate myopia, which is not increasing, is no bar to any occupation which does not prohibit the wearing of glasses. Hypermetropic eyes are, when unassisted, of course unsuited for near work; but since the defect is one which can be entirely corrected by glasses, it need not in any way interfere with the choice of a business or profession, provided glasses can be used. In the case of those, however, who are not permitted to wear spectacles, it must be borne in mind that, as the accommodation becomes weaker, distant vision will become impaired.

The question is often asked whether a patient with a certain amount of ametropia will by it be rendered ineligible for one of the public services. Until recently much hardship was entailed upon candidates owing to the impossibility of ascertaining, before they commenced their studies, what standard of vision was required. Accordingly, Sir Joseph Fayrer and Mr. Macnamara have drawn up a code of rules showing the standard required for each branch of the Indian service; * much discretion, however, is still left in some cases to the examiner.

For the Pilot Service a candidate must be emmetropic, and have normal vision, in each eye. For the marines ametropia of over 1 D in either eye will disqualify. For both these normal colour-vision is required.

For the Indian Civil and Indian Medical Services vision with correcting glasses must be $\frac{6}{6}$ in one eye, and not less than $\frac{6}{9}$ in the other. Posterior staphyloma will exclude in the first case if the myopia be over 2·5 D, and in the second if it be over 5 D.

Candidates for commissions in the British army must be able to read without glasses not less than $\frac{6}{36}$ with each eye and 0·8 Snellen, and with glasses not less than $\frac{6}{6}$ in one eye and $\frac{6}{12}$ in the other. Squint, inability to distinguish the principal colours, or any morbid condition in either eye, subject to the risk of aggravation or recurrence, will disqualify.†

For the Army Medical Staff the Board of Examiners must certify that the candidate's vision is "sufficiently good to enable him to perform any surgical operation without the aid of glasses." Recruits may be tested with the dots.

CHAPTER XIV.

AFFECTIONS OF THE OCULAR MUSCLES.

THE function of the external muscles of the eyes is to direct the two visual axes to the same point in space, and both their mechanical relations to the eyeball and also their connections with the nervous system are such as to allow of this being accomplished with the least expenditure of nerve force.

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* "Defects of Vision which Disqualify for the Indian Government Service." J. A. Churchill, 1886.

† Longmore, "Illustrated Optical Manual," 1888.

Each eyeball is very nearly spherical in form, and lies in a socket of similar curvature, which is formed by a condensation of the anterior layer of the cellular tissue of the orbit, and goes by the name of Tenon's capsule. By means of its muscles each globe is rotated round a point, the position of which in a normal eye nearly corresponds with that of its geometric centre. These muscles are six in number, and are arranged in three pairs, the members of each pair rotating the globe round a common axis in opposite directions. When the muscles are in the condition of least innervation the visual axes are parallel and directed straight forwards. The movements of the eyes to be presently described are considered in relation to this (the "primary") position.

The four recti arise from the apex of the orbit, and, passing forward, diverge from one another, thus forming a hollow cone, in which the globe is embraced. Each muscle to reach its insertion pierces the capsule of Tenon, and as it does so receives a sheath, which is an offshoot from the capsule, and becomes converted into a flat tendon, which blends with the sclerotic a few millimetres from the margin of the cornea. The exact point of insertion is different for each muscle, the most anterior being that of the internal, which is 6·8 mm. from the corneal margin.

It will be convenient to consider the action of the muscles from two aspects: first, in reference to the direction in which they cause the anterior pole of the eye (*i.e.* the centre of the cornea) to deviate from the primary position; and secondly, the rotation they produce of the globe round its antero-posterior axis, the latter being conveniently expressed by the inclination which is given to the vertical meridian of the cornea.

The axis of the superior and inferior recti lies in the horizontal plane, and is nearly but not quite transverse, its inner extremity being a little in advance of its outer (R R, Fig. 82). The superior recti accordingly displace the anterior poles upwards and inwards, and cause the upper extremities of the vertical meridians of the corneæ to converge. The inferior recti act in the opposite way in both respects. The internal and external recti rotate the globe round a vertical axis, moving the cornea inwards and outwards respectively. Of the third pair of muscles formed by the obliqui, the superior arises, like the recti, from the apex of the orbit, and passes forwards to the upper and inner angle; on reaching the margin of the orbit the muscle, temporarily converted into a rounded tendon, passes through a fibrous ring or pulley (Fig. 82), and then runs backwards and outwards to reach its insertion in the outer and posterior quadrant of the superior hemisphere. The inferior oblique arises from the anterior and inner part of the floor of the orbit, and passes backwards and outwards beneath the inferior rectus, and then between the external rectus and the globe, to be inserted in the outer and posterior quadrant of the inferior hemisphere. The axis on which these muscles rotate the globe (O O, Fig. 82) lies in the horizontal plane, and has its anterior extremity inclined outwards, forming an angle of

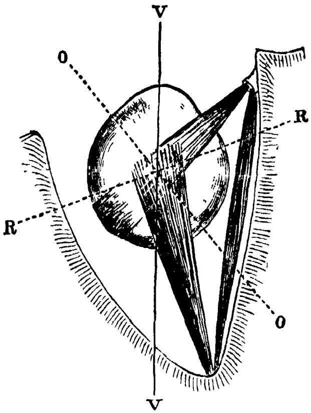

Fig. 82.—Axes of Rotation of the Superior and Inferior Recti and Obliqui.

about 65° with the visual axis, v v. The superior oblique turns the centre of the cornea downwards and outwards, and causes its vertical diameter to incline downwards and outwards, while the inferior has the opposite effect. The exact direction and mode of insertion of the reflected portion of the superior oblique varies considerably. The angle which it forms with the visual axis is probably to a great extent dependent upon the prominence of the globe and the dimensions of the orbit. Sometimes the muscle is in relation with the globe for a considerable portion of its circumference, while in another class of cases it arches over the globe, without touching it, till it has nearly reached its point of insertion. Processes sometimes are given off from the main part of the tendon insertion, which pass close to the optic nerve. It is evident that the movements of the globe produced by the muscle will be somewhat different in different cases.*

It is evident that if two muscles which are not opponents act at the same time, the globe will be rotated on an intermediate axis. Thus if the superior rectus (which directs the anterior pole upwards and inwards) acts in conjunction with the inferior oblique (which turns it upwards and outwards), the inward and outward movement of the two muscles will counteract each other, and the resultant will be an upward movement.

Since the object of the various movements of the eyes is to direct both visual axes to the same point, some are frequently, and others never, associated. Thus it is often necessary to turn both eyes up, down, to either side, or inwards, but never to turn one up and the other down.

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* For fuller details, *see* Stilling, "Die Entstehung der Kurzsichtigkeit," 1887; and "Schadelbau und Kurzsichtigkeit," 1888.

The following table shows what muscles are concerned in imparting any given direction to the eyes :

1. Upwards	Superior recti. Inferior obliqui.
2. Downwards	Inferior recti. Superior obliqui.
3. Inwards	Internal recti.
4. Outwards.	External recti.
5. To the right. . . .	Right external rectus. Left internal rectus.
6. To the left	Left external rectus. Right internal rectus.

Movement in any intermediate direction is produced by the muscles which are concerned in the movements into which it can be resolved ; thus movement upwards and to the left is produced by the muscles in groups 1 and 6, the upward and inward movement by those in 1 and 3, and so on.

Convergence is quite independent of the conjugate movements of the eyes to the right and left, up and down, etc., so that if a certain amount of convergence be given to the eyes, it can be maintained while they are turned in different directions. On the other hand, convergence and accommodation are intimately associated. These facts have an important bearing on the pathology of concomitant strabismus.

Under no circumstances can a motor impulse be sent to one eye only ; but although transmitted to both eyes, it does not of necessity cause movement of both ; for if there be simultaneous and equal stimulation of opponent muscles, no change of position will take place. For example : the attention is directed to an object which lies in front of the left eye, and is gradually being approximated along its visual axis ; as it approaches, an impulse to convergence is sent to the internal recti of both eyes ; but as the object lies not in the middle line, but to the left of it, there is a simultaneous impulse to conjugate lateral movement to the left, *i.e.* to the left external and right internal recti. In the left eye the two recti neutralise each other, and the eye does not move; in the right eye, on the contrary, the convergent action of the internal rectus is reinforced by its lateral action, consequently the right alone moves.

The nerve supply of the muscles is simpler than might at first sight be thought requisite for so complicated a mechanism; the superior oblique is supplied by the fourth, and the external rectus by the sixth, and all the remainder by the third. Muscles supplied by the same nerve are necessarily simultaneously affected by lesions of that nerve; but identical nerve supply no more of necessity indicates association of function than does the fact of a bundle of telegraph wires running along the same street indicate that they effect communication between the same places. The nerve trunks are simply bundles of fibrils, which are made to run together for convenience, but which may arise from different nuclei in the brain, and at their distal extremities be connected with different muscles.

We at present know little from actual demonstration of the course of the ultimate nerve fibrils within the brain, but from the results afforded by experiment, the symptoms produced by pathological lesions, and from the association of muscles in the normal condition, we can ascertain the position of the centres with which they are connected with almost as much certainty as if they could be demonstrated by dissection.

The motor nerves of the eye all arise from that portion of the grey matter of the brain which extends from the anterior part of the third to the floor of the fourth ventricle. By far the larger part of this area contains the nuclei of origin of the third nerve; indeed, this nerve, arising as it does from so many nuclei, and supplying muscles which in some instances are opponents, is to be looked upon rather as a collection of nerves than as a single nerve.

The most anterior nucleus is that governing the muscle of accommodation,* and that for the sphincter of the pupil comes next; then follow the nuclei of origin of the remainder of the third (concerning the relative position of which there is some doubt, but that of the internal rectus would seem to be most anterior), then we have the fourth nerve, and most posteriorly, in the floor of the fourth ventricle, the nucleus of the sixth. It is disputed whether the fibres of the fourth nerve decussate with those of the opposite side or not.

Recent observations have shown that there exists an important relation between the third and sixth nerves, which facilitates conjugate movements to the right and left. From the nucleus of the sixth nerve arise fibres, some of which pass to the external rectus of the same side; but another bundle passes across to the opposite side, and blending with the third nerve of that side, but without apparently passing through its nucleus, supplies the internal rectus. According to this, a nerve impulse emitted from the nucleus of the sixth would turn both eyes to that side.

The eyes of man, unlike those of most of the lower animals, are directed straight forwards when at rest. Consequently, although each commands a portion of space on its own side which is inaccessible to the other, the larger part of the visual field is common to both. The curtailment of the whole field thus produced is more than compensated for by the great mobility of the head and of the eyes; while the unconscious mental comparison of the two retinal images gives better impressions of depth, relief, and solidity than can be obtained from one eye only.

This can be illustrated by the stereoscope. In this

* Hensen and Volkers, *Arch. of Oph.*, vol. xxiv. p. 1.

instrument a picture of the same object is placed before each eye. These differ just as the projections of the two retinal images of the same object would, and they are viewed through prisms and lenses which necessitate the employment of the same muscular effort which would be required in looking at the real object. The result is, that the object appears to stand out in bold relief.

A very efficient and simple illustration of binocular vision, and test as to its presence, is furnished by Hering's apparatus, which consists of a string stretched horizontally at a convenient distance from the eyes. This is viewed through a wooden frame, which cuts off the peripheral parts of the visual field. Small objects are dropped from a height of a few inches close to the string, and the patient is asked each time to say whether the falling body passes the string on its distal or proximal side. With one eye alone it will be found quite impossible to form an opinion, but with both open an observer with binocular vision experiences no difficulty.

The two retinal images are only "fused" (*i.e.* excite in the consciousness the impression of a single image) when their several points fall on "corresponding" areas of the two retinæ. The yellow spots situated at the extremities of the visual axes correspond; and one may say, with practical accuracy, that if the two retinæ were superposed, the points which coincided would be "corresponding;" so that the right, left, upper, and lower quadrants of the one retina correspond respectively with the quadrants of the same name in the other. In any given position of the eyes certain points in space have their images on corresponding points of the retinæ, and are therefore seen singly by the two eyes; the term "horopter" is given to the combination of all such points. Points which do not lie within the horopter would appear double if the mind took cognisance of both retinal images. As a matter of fact, however, we do not under ordinary circumstances see any points double, although there must always be images of some of these points on the retinæ. This is due to several causes: in the first place, if the one image is farther from the yellow spot than the other, it appears less vivid, and is easily disregarded by the mind. The images of points which lie at a different distance than that for which the eyes are accommodated are also easily disregarded, the mind not taking very accurate note of any objects except those on which its attention is actually fixed, and to which the visual axes are directed. We shall presently see how easily double vision is produced, when images are formed on non-corresponding points under unusual or abnormal conditions.

One cannot but be struck by the rapidity and certainty with which the visual axes can be directed to any given point, the movement often requiring as it does the exact co-ordination of several muscles in the two eyes. There can be no question that the power of moving the eyes symmetrically in obedience to the will, like other complicated acts, is only acquired by practice and education. A new-born infant does not direct its eyes to a bright object, but rolls them aimlessly about; and when in a few days it does acquire the power of directing its eyes, it seems to require some time longer to learn to keep them fixed in any direction for more than a second or two. Occasionally children are backward in learning to co-ordinate their ocular muscles, just as some are in learning to walk; in such cases a suspicion of blindness is often aroused, and many cases of supposed recovery from amaurosis in infancy are no doubt of this nature.

It is the instinctive desire to combine the images formed on the two retinæ into a single mental picture, by bringing them on to corresponding retinal areas, which gives the stimulus to this co-ordination of movement; and if from any cause the retinal images are imperfect or absent, if there is a break in the conducting nerve track, or if from defect in the nerve centres the mind is unable to project the retinal images, the child never learns to co-ordinate the ocular muscles, and, as a consequence, we get that rolling or oscillating motion of the eyes which is called *nystagmus.*

Nystagmus.—The character and extent of the movements in this affection vary much in different cases. Occasionally they consist in a rapid oscillation which is only visible upon close inspection; more frequently the eyes undergo free rolling movements.

A form of nystagmus occasionally comes on in coal-miners. As far as is known, it only occurs in those who are employed in cutting the coal while lying on their side with their eyes turned in an oblique upward direction. It is therefore probably due to the strain upon the ocular muscles, and is independent of defective illumination, to which it has sometimes been attributed.*

No treatment is of any avail for the nystagmus which comes on in early life as the result of defective vision. Even when the movement has been purely in the horizontal plane, division of the lateral recti has been tried and found useless, nor does the nystagmus diminish when the vision is improved. Miners' nystagmus, on the other hand, generally recovers as soon as the patient changes his occupation.

Insufficiency.—The strength of the ocular muscles is to be estimated on a somewhat different principle to other voluntary muscles. We gauge the power of the latter by the work which can be done when the resistance offered by the tonic contraction of the opponent muscle, friction, etc., have been overcome, but in the case of the ocular muscles these latter constitute the only resistance; hence their *relative* is of much greater importance than their *actual* power. If the normal relation exists between the internal and external recti, parallelism of the visual axes will be the position of rest. But if, as is very frequently the case, the internal recti are slightly weaker than the external, parallelism can only be maintained by a constant effort. The result will of course be the same, whether the disproportion is due to an excess of power in the one pair of muscles, or to a deficiency in the other. The desire for single binocular vision leads to an instinctive and usually unconscious effort, which is sufficient to overcome a slight inequality of the muscles. But if from any cause binocular vision is rendered impossible, the eyes are allowed to assume their position of rest. This explains why not unfrequently, when the sight of one eye has been much impaired, a squint becomes developed.

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* *See* Snell, Trans. Ophthal. Society, vol. iv. p. 315.

Apart from the relative strength of the muscles, the position of rest varies in accordance with other factors, the exact influence of which is not yet fully known; among such may be mentioned variations in the length of the muscles, and the positions of their attachments, in the relations between processes of fascia and the muscles, and in the form of the orbits.

When the inequality between the internal and external recti is considerable, or when, with even a slight inequality, the general muscular tone is lowered, the attempt to fix both eyes upon a near object for any length of time gives rise to a feeling of fatigue and sometimes to headache, symptoms, in fact, which are similar to those produced by hypermetropia. (*See* page 406.) It often therefore becomes necessary to ascertain whether there is any relative *insufficiency of the internal recti.* The simplest way of doing this is to render fusion of the two retinal images impossible by means of a prism of about 6° with its base upwards or downwards, placed before one eye. This displaces one retinal image, and, since the eyes can only be moved in the vertical plane together, the patient will see two images of any object looked at, one above the other. If the normal relation exists between the muscles, on accommodating the eyes for any given distance the corresponding amount of convergence will be used, and the two images will lie in the same vertical plane. Undue convergence will be shown by the image being displaced towards the side of the eye which sees it, and divergence by crossing of the images.

One of the best known test-objects for this purpose is that known as Graefe's. It consists of a vertical line with a dot in its centre; when there is normal convergence a vertical prism will cause reduplication of the dot, but the lines will be fused into a single image. The weak point in this test is that the desire for fusion is not removed by the prism. A more accurate test is furnished by the employment of series of minute red and green squares arranged alternately in a vertical line, viewed through glasses of identical colours—one before each eye.

It is not always possible by simple inspection of the eyes to estimate the relative direction of the visual axes, for the latter do not as a rule cut the cornea exactly in their centres, but a little to the inner side. The angle thus formed between the axis of the cornea and the visual axis is called the angle *alpha*. In the normal condition this angle measures about only 3° to 4°, and therefore causes no appreciable deviation of the eyes; but if, as is sometimes the case in hypermetropia, it is unusually large, the eyes may appear to be divergent, although the visual axes are really parallel. In myopia the visual axes sometimes cut the corneæ to the outer side of their centres; the angle *alpha* is then said to be negative, and there will be apparent convergence when the visual axes are parallel.

If we wish to measure the actual amount of divergence and convergence that can be employed, we may do so in the following manner: To measure the divergence, place prisms with their bases inwards in front of the eyes; this displaces the retinal images inwards, and the eyes must be rotated outwards if the images are to fall upon the yellow spots and the object is to be seen singly. The strongest prisms which can be worn while a distant object is seen singly indicate the maximum degree of divergence. When there is a prism before each, the total effect is that of a prism equal to their sum placed before one eye.

Convergence might be similarly measured with prisms with their bases outwards, but, owing to the great strength of the prisms required, the plan is inconvenient. It is simpler to see how near an object can be brought without diplopia resulting.

The amount of divergence or convergence might be indicated by the number of degrees of a circle through which the eyes rotate; but a more convenient plan is the following, since it indicates at the same time the relation between convergence and accommodation:

The position of rest is assumed to be parallelism. The unit of measurement taken is the convergence necessary in order that both eyes may fix an object in the median plane at a metre distance. This amount of convergence is spoken of as a metrical angle (1 ma.). A distance of half a metre would require 2 ma. of convergence, a third of a meter 3 ma., and so on. (The actual value of the metrical angles will of course vary with the distance between the eyes; taking 64 mm. as the average for the latter, the value of the metrical angle would be 1·83°, for each eye.) It will be evident at once that the accommodative and convergent efforts are indicated in the same way. For instance, a pair of emmetropic eyes looking at an object situated at 33 cm. would use 3 D ($\frac{100}{33}$) of accommodation and 3 ma. of convergence. Each metrical angle corresponds to a prism of about 7°.

In noting the movements of the eyes, parallelism is indicated by zero, divergence and convergence by the signs − and + respectively.

For example, prisms with their bases inwards equivalent to 7° can be overcome; this is indicated by − 1 ma. The nearest point of binocular fixation is 10·5 cm.; positive convergence is therefore $\frac{100}{10\cdot5}$ = + 9·5 ma. The total range of movement, or amplitude of convergence, is therefore 1 + 10·5 = 11·5 ma. The above represents the normal condition; it is evident that it may be departed from in many ways. The amplitude of convergence may be normal, but it may be displaced to the positive or negative side; or the amplitude may be diminished at the expense of either the positive or negative portion, or both. Slight abnormalities can be remedied by the use of prisms; the more marked cases require tenotomy of the preponderating muscles, with or without advancement of the weaker.*

As was seen to be the case with accommodation, it is impossible without fatigue to use the whole power of convergence for any length of time. In order that work at a given distance should be carried on continuously, the patient must have an amount of convergence in reserve equal to twice the amount required at any moment. For example, if the work lies at 33 cm., a convergence of $\frac{100}{33}$ = 3 ma. is required; to maintain this the patient should have a total positive convergence of 9 ma.

When a patient is wearing spherical lenses, and a prismatic effect is required, it can be obtained by decentering the lenses. A convex lens is equivalent to two prisms with their bases in apposition, a concave lens to prisms with their bases in opposite directions. In order, therefore, to obtain the effect of prisms with their bases inwards (diverging prisms), convex lenses must be displaced inwards and concave lenses outwards. The prismatic effect will depend upon the amount of decentering. When the axes of the two glasses coincide, they have the same optical effect as if they were parts of a single large lens (Fig. 83). Under such circumstances an equal effect would be produced upon convergence and accommodation. If, for example, an object lay at the focus F of such an imaginary lens, neither convergence nor accommodation would be required. Such lenses are called orthoscopic; their foci would coincide, and only a single image of an object would be formed by them on a screen.

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* *See* Landolt, translated by Law, *Oph. Record*, p. 185; 1886. Nagel, "Graefe-Saemisch Handb.," vol. vi.

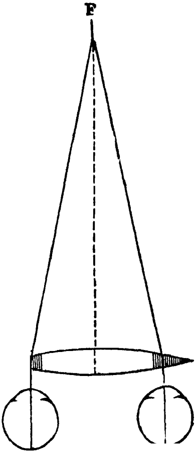

Fig. 83.

Paralysis.—When a single ocular muscle is partially or completely paralysed, its opponent causes the eye to deviate in the direction opposite to that of the normal action of the affected muscle. As a consequence of this deviation or squint, the image of an object to which the visual axis of the unaffected eye is directed does not fall in the deviating eye on the yellow spot, but on that side of it towards which the cornea is deviated. This is at once evident from Fig. 84, in which the left eye is depicted as having its visual axis V *v* directed to a distant object, and the right eye as deviating inwards; in the latter the secondary axis *a b*, on which the image of the object must be formed (and which will be parallel to the visual axes of the normal eye), cuts the retina at *b*, on the inner side of *v*, the yellow spot.

From this displacement of the retinal image, double vision or "diplopia" results. We can judge of the position of an object either by a sense of the muscular effort required to direct the visual axes towards it, or by the position of its image on the retina when the visual axes are not directed to it; thus, if, when the muscles are in the condition of least innervation (and the eyes consequently directed straight forwards), images of an object are formed on the retinæ to the left of the yellow spot, we know that the object must lie to the right. When, however, an eye deviates in consequence of paresis of one of its muscles, both these methods of estimating position fail us. Putting for the present the unaffected eye out of the question, we will suppose that, in the instance depicted in Fig. 84, an attempt is made to direct the visual axis of the right eye to an object lying straight in front of it (say, in the direction of *a*); a nerve impulse would be required which in the

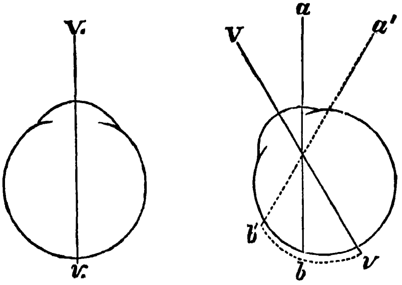

Fig. 84.

normal condition would direct the eye to a point still farther to the right (say, to *a′*); accordingly the muscular effort made produces the impression that *a* lies at *a′*. But the position of the retinal image also causes an error. Let us assume that in the above case no muscular effort is made, and that the eyes therefore remain in the position depicted, and that the consciousness is directed to an object which lies straight in front of the patient, in the direction of the line *a b*, its image will fall at *b*, to the inner side of the yellow spot. But we have seen that when the muscles are in the condition of least innervation (as is the case in the instance we are considering), an image formed to the inner side of the yellow spot is projected by the consciousness to the right; hence this eye will see an object on the line *a b* farther to the right than its true position (the exact direction in which it will be projected can be found by seeing to what point in space *b* would correspond if the eye were in its normal position). If in Fig. 84 the dotted line represent the normal position of the retina, the position of the retinal image (indicated by *b′*) would then lie as far to the inner side of the yellow spot as *b* did from *v*. The point in space to which *b′* corresponds can be found by drawing the line *a′ b′* through the optical centre of the eye. The deviating eye therefore sees a *false* image of *a* at *a′*, and, since the left eye sees the object in its true position, it is evident that double vision must result when both eyes are open.

The displacement of the false image is proportionate to the amount of deviation, and in the opposite direction.

The diplopia is most troublesome to the patient when there is only a slight separation between the images, since the false image, then falling near the yellow spot, is seen almost as vividly as the true one.

When it falls on a more peripheral part of the retina, it is easily disregarded, or at any rate causes no difficulty in judging of the true position of the object.

The direction and extent of a deviation of one eye may be roughly estimated in the following manner: The patient is directed to look at an object (the surgeon's finger) held at a distance of about three or four feet; each eye is then covered in succession; if there is no deviation, *i.e.* if both eyes are directed to the finger, each as it is uncovered will see it at once without making any movement. If, on the contrary, there is any deviation of one eye, a correcting movement will have to be made to see the finger when the other eye is covered. By the direction and extent of this movement the character and degree of the deviation can be seen.

It is, however, often desirable to measure the deviation accurately. This may be done in either of the three following ways: (1) Measure on the lower lid the difference between the points coinciding with the vertical meridian of the cornea when a distant object is fixed by the normal and the deviating eye respectively. (2) Place the deviating eye in the centre of the perimeter, and direct the patient to fix a distant object with the other eye; if the eye in the centre did not deviate, it would be directed to zero. It is required to find to what point on the arc of the perimeter it is directed. If a small flame, such as that from a wax match, lie in the same vertical plane as the optic axis of the eye, its image, formed by reflection in the cornea, will also lie in that plane, and will be visible to the surgeon when he places his eye above or below the flame. If, therefore, the flame be moved along the arc of the perimeter, just below the level of the horizontal meridian of the eye, while the surgeon places one eye just above it, it is easy to note the point at which the reflected image appears to lie in the centre of the cornea; the position of the flame on the arc of the perimeter at the moment will indicate the direction of the optic axis of the eye. It is true that the optic axis does not exactly coincide with the visual, but it is sufficiently near for the purpose.

(3) Find the prism which, with its base towards the paralysed muscle, corrects the diplopia. In Fig. 85 the right eye is shown deviating inwards, in consequence of paralysis of its external rectus; the image, therefore, of a distant object to which the other eye is directed will fall at *b*, to the inner side of the yellow spot *v*′, and be projected to the right. A prism P with its base outwards, which brings the image on to the yellow spot, will remove the diplopia.

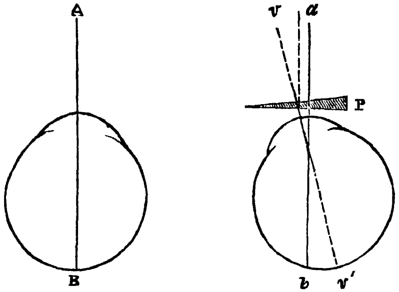

Fig. 85.—Action of a Prism in Correcting Diplopia.

vv′. Visual axis. Left eye, looking at a distant object in the direction of A, receives its image on the yellow spot, B. The right eye, in consequence of its deviation, receives the image of *a* to the inner side of *v* at *b*, and diplopia results. The prism P causes the ray *a b* to deviate to *v*′, and removes the diplopia.

A deviation which is so slight as hardly to be recognisable by inspection will yet cause diplopia, and the latter then becomes an important aid to diagnosis. To utilise it for this purpose, it is in the first place necessary to discriminate between the two images. This can be done by placing a coloured glass before one eye, and directing the patient to look at a lighted candle held about three yards away; the image formed in the eye which has the coloured glass in front of it will of course appear coloured. Since the displacement of the image is in the reverse direction to that of the eye, it follows that if the eyes are too convergent, so that the visual axes meet on the proximal side of the object, the images will be seen side by side, and the image seen by each eye will lie to its own side; in this case the diplopia is said to be "homonymous." If, on the other hand, the visual axes are actually divergent, or if they cross beyond the object, the image formed in the right eye would appear to lie to the left of the other, and *vice versa*, and the diplopia would therefore be "crossed."

Not only are we able by this test to ascertain the direction of the deviation, however slight it may be, but we can discover which muscle is at fault. The distance between the two images is proportionate to the amount of deviation, and this will become greater when an attempt is made to turn the eyes in such a direction that the affected muscle is called upon to do its share of the work. For instance, if there is homonymous diplopia, we know that there is undue convergence, and therefore that one of the external recti is at fault. If the right muscle is the culprit, that eye will lag somewhat behind when the candle is carried to the right, the patient being directed to follow it with his eyes but not to move his head, and there will be a corresponding increase in the distance between the images; while when the candle is carried to the left, the images come nearer together, and at length fuse into one. If, on the other hand, the diplopia is crossed, it will indicate paresis of one of the internal recti; if it increases on looking to the right, it is the left muscle that is affected, because it is this muscle that is called into play in looking to the right. Crossed diplopia is more marked in looking upwards, and homonymous in looking downwards.

When the external rectus is affected, both images are erect as long as the eyes are not directed above the horizontal plane; but when they are turned upwards, and to the affected side, they are no longer parallel, but their upper extremities diverge. This sometimes gives rise to an erroneous diagnosis of one of the oblique muscles being in fault. In the normal condition, in looking upwards and to one side the vertical meridians of the cornea slant upwards and to that side; if, however, one eye lags behind in the outward movement, in consequence of a defective external rectus, its rotation on its antero-posterior axis will be less than in the sound eye, and consequently the vertical meridians of the cornea will converge above, and the projected images be no longer parallel, the true image appearing to be the erect one.

In the same way, when either the superior or the inferior rectus is affected, there is crossed diplopia, as well as some obliquity of the false image, and vertical displacement which increases as the eyes are turned in the direction of the affected muscle. When the superior rectus is at fault, the upper extremities of the images diverge; and when the inferior, the lower extremities diverge. As a rule, the lower image appears to the patient to be nearer than the other.

We have seen that the superior oblique not only moves the centre of the cornea downwards and outwards, but rotates it so that its vertical meridian assumes an oblique direction downwards and outwards. This will be at once evident from Fig. 86, which represents diagrammatically a transverse vertical section of the orbits, showing the posterior hemispheres of the globes, with the oblique muscles.

When the superior oblique is paralysed, not only does the centre of the cornea deviate upwards and outwards, but the vertical meridian of the globe assumes an oblique direction downwards and inwards. The result of this is that the false image of any object, undergoes a double displacement; it is projected relatively to the true image downwards, and to the side of the affected eye, and it also undergoes a rotation which causes its lower extremity to slant away from the true image. In Fig. 86 *b a* and *b′ a′* represent the position of the retinal images of such an object. In the left eye, which is in the normal position, the image falls on the vertical meridian, and is therefore projected as a vertical image, *a b* (Fig. 87); but in the right eye *b′* lies in the upper and inner quadrant of the retina, and *a′* in the lower and outer quadrant; *a′* would therefore have its projected image in the upper and inner, and *b′* in the lower and outer, quadrant of the visual field; and since the whole projected field in the right eye is displaced downwards and outwards,* the relative position of the projected images would be that depicted in Fig. 87. The symptoms produced by paralysis of the inferior

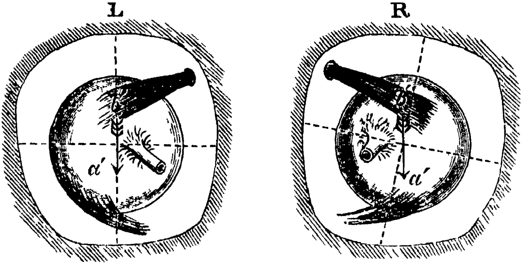

Fig. 86.—Diagrammatic Section of Orbits, showing Posterior Surface of Globes. Paralysis of Right Superior Oblique.

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* The diplopia is therefore *homonymous*, while when the inferior rectus is affected it is *crossed*.

oblique are the exact opposite of those just described, but this muscle is seldom paralysed alone.

As might be expected, the muscles supplied by the third nerve are often paralysed simultaneously. The upper lid falls over the cornea, and can only be slightly raised by the action of the occipito-frontalis; the globe is rotated outwards and fixed; the pupil is inactive and dilated (the latter, however, not so fully as when atropine has been applied); and near vision is defective from paralysis of the accommodation.

It must be borne in mind that when the action of one muscle is eliminated, the resultant of the combined action of the other muscles must be altered, and the position of the eye is not therefore solely determined by the contraction of the direct opponent of the paralysed muscle; although, therefore, in recent cases the above-described symptoms are always present, in old-standing cases they may be somewhat modified.

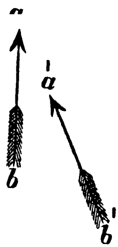

Fig. 87.—The Projections of the Retinal Images depicted in preceding figure.

It must be remembered that the movements of the two eyes are intimately associated, and that one cannot be moved without its fellow; accordingly, if, when a muscle is paralysed, the sound eye be covered, and the patient be directed to fix an object in the middle line with the squinting eye, the movement that this eye has to make in order to fix, is accompanied by a similar movement of the covered eye, and, as a consequence, the latter deviates. This deviation of the sound eye when the affected eye fixes, is called the secondary squint. Since, however, a greater stimulus has to be sent to the affected muscle than would be required under normal conditions, and as the same stimulus is of necessity sent also to the muscle of the sound eye, it follows that the latter makes a greater movement than the affected eye, and the secondary squint is therefore greater than the primary.

In addition to the symptoms of squint and diplopia, there is very often a displacement of the head, by which the patient endeavours to counteract the displacement of the eye. Thus, if the right external rectus is affected, the head is turned to the right in order to correct the displacement of the eye to the left; and the same for the other muscles, the head always being carried in the direction of action of the affected muscle. There is also often vertigo from the confusion caused by the false image; and if the sound eye be covered, or if the deviating eye should happen to be the better of the two, the patient's gait, if the paralysis is at all recent, is reeling and unsteady.

Paralysis of the ocular muscles may arise from several causes, but by far the most common is syphilis, and this may induce it in several ways: there may be a gumma either on the main trunk of a nerve, or on a filament going to a single muscle; there may be syphilitic periostitis at the apex of the orbit, in which case several muscles supplied by different nerves are generally implicated; there may be syphilitic deposit in the cavernous sinus, when not only will all the ocular muscles be paralysed, except sometimes the external rectus, but there will be anæsthesia of the cornea from implication of the first division of the fifth nerve; finally, the lesion may exist in the brain, either at its base, or at the nuclei of origin of the nerves (these latter cases will be referred to again presently). Whatever the nature of the lesion, it shows itself, as a rule, late in the disease, frequently after a long period of quiescence.

Rheumatic thickening of the nerve-sheath, or periostitis at the apex from the same cause, may cause paralysis; in these rheumatic cases the paralysis is sometimes preceded by great pain over the orbit.

Exposure to cold occasionally causes paralysis of the sixth nerve, and both this and the fourth, and especially the latter, are liable to be affected by blows in the region of the orbit, the actual lesion probably being effusion of blood into the nerve-sheath.

In the early stage of locomotor ataxy a temporary diplopia is sometimes met with, which would seem to be due to a loss of co-ordinating power rather than to actual paralysis of a muscle; the latter is, however, not uncommon at a later period of the disease.

Many cases are met with in which the paralysis of a single muscle occurs suddenly and without any known or suspected cause.

When several muscles of one eye which have not the same nerve supply are affected, the seat of the mischief must be diagnosed as being situated where their nerves are in contact (as at the apex of the orbit or in the cavernous sinus). When muscles in both eyes which are commonly associated in any action are affected, the nerve centre which governs that action is indicated as the seat of the lesion. In this case the motor nerve may still be intact, and convey impulses to the muscle from another centre; thus the power of convergence may be completely lost, and yet each internal rectus may act perfectly with the external of the opposite eye (as in looking to the right or left); and, on the other hand, the conjugate movement to one side may be impaired, while convergence is intact.

Ophthalmoplegia externa.—An important class of cases has been described under the term "ophthalmoplegia externa," in which all, or the majority, of the muscles in each eye become successively paralysed. The symptoms first noticed are frequently ptosis and a difficulty in rotating the globes upwards. It is soon seen that, although no muscle is completely paralysed, yet that the eyes are moved in all directions with great difficulty; complete paralysis of nearly all the external muscles soon follows, the accommodation and the sphincter of the pupil usually remaining unaffected. The lesion is located in the nuclei beneath the aqueduct of Sylvius and in the floor of the fourth ventricle. These cases are as a rule exceedingly chronic in their course, are usually traceable to syphilis, and are often much benefited, and not unfrequently cured, by large doses of iodide of potassium. Occasionally, however, the disease progresses and attacks other nerve centres (as that for deglutition), and ends fatally.*

The treatment of paralytic affections of the ocular muscles consists in the first place in remedying as far as possible the condition which caused the paralysis, and in the second in preventing secondary atony of the affected muscle. In the syphilitic cases iodide of potassium, combined or not with mercury, is indicated; in the rheumatic, salicylic acid and its compounds, alkalies, or iodide of potassium are likely to prove of service, and in this form counter-irritation in the form of a blister to the temple often relieves the pain, and possibly has some effect in promoting the absorption of effusion into the nerve sheaths. All paralytic affections of the ocular muscles are apt to be exceedingly chronic, often lasting many months, but they generally eventually yield to treatment, or disappear with lapse of time. After the nervous lesion has recovered, delay may arise in the complete restoration of the function of the muscle, owing to atrophic changes having taken place; and repeated faradisation is useful in guarding against the occurrence of this, and in helping to remove it when present. It is probably not of much use to apply the reophore over the closed lids, as the effect of the current is in that case almost entirely expended on the orbicularis; the sensitiveness of the conjunctiva, however, renders it difficult to apply it directly to it, unless very weak currents are employed. It might perhaps be worth a trial to render the conjunctiva anæsthetic with cocaine before applying the reophore. A very convenient and safe way of applying a weak current has been suggested by Dr. Buzzard, namely, for the surgeon to place himself in the circuit, and use his index finger as a reophore.

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* For a fuller account of such cases the reader is referred to Mr. Hutchinson's paper: Med.-Chirurg. Trans., lxii. 311, and Mauthner: Beitrage aus d. gesam. Augenheilkunde. "Nuclearlähmung."

When a paralytic squint has been almost cured, or is very slight, much good may sometimes be effected by prisms. The nearer the true and false images are to each other the more troublesome is the diplopia; if, therefore, prisms are given which very nearly, but not quite, correct the diplopia, the inconvenience caused by the remainder will stimulate the patient to make a greater effort of convergence, or to use both external recti to overcome it. There are, however, several practical inconveniences attending the use of prisms, which limit their range of utility. In the first place, only weak prisms can be worn, because of the weight of the strong ones, and because of the chromatic aberration which they produce; prisms making a total of 8° represent about the limit. Again, the deviating effect of a prism differs according to the angle at which the rays impinge on it; hence they have not quite the same effect in near and distant vision. They can, of course, only be of use in stimulating the muscles to contraction when applied to convergent or divergent squint, because the one eye cannot, as a rule, be rotated upwards or downwards by a voluntary effort without the other.

The prism must be placed before the affected eye with its base towards the affected muscle, and should be a little weaker than the one that corrects the diplopia. It is generally best to divide the prism between the two eyes, in which case their bases must be placed symmetrically in relation to the middle line; thus if a prism of 8°, base outwards, is required to correct the diplopia caused by paresis of one external rectus, a prism of 3° should be placed before each eye with its base outwards.

Not unfrequently when paralysis has existed a considerable time, and has to a great extent yielded to remedies, there succeeds a stationary period, in which the deviation is not conspicuous, but the diplopia continues to be very worrying; in such cases it would seem as if the lesion of the nerve had been repaired, but that the muscle, through long disuse, had become atrophied, and was unable to counteract the tonic contraction of its opponent. Much may often be done by gymnastic exercises of the muscle by means of galvanism or by the aid of prisms. The contractions produced by galvanism tend to improve the tone of the muscle, and will generally prevent atonic changes if used sufficiently early. When a sufficient trial has been given to these measures, and some squint still persists, tenotomy of the opponent muscle is called for, but it is useless to perform the operation unless the affected muscle possesses faradaic excitability.

Recently Dr. Spalding* has suggested that passive motion of the muscle should be employed to prevent or remove atony in chronic cases; the suggestion is not new, having been put forward by Prof. Michel in 1877, but was hardly practicable before the introduction of cocaine. The conjunctiva having been rendered completely anæsthetic, the globe is seized with forceps over the insertion of the paralysed muscle; the globe is then rotated alternately in the direction of action of the affected muscle and in that of its

* *Archiv of Ophthal.*, Dec., 1886.

opponent for about two minutes, and repeated daily. The results are said to be exceedingly good, but the writer finds that the treatment is not well borne, the anæsthesia produced by cocaine being insufficient for the purpose.

Concomitant squint.—We come now to the consideration of a form of strabismus in which there is no paresis of any muscle, and consequently no curtailment of the movement of either eye, but in which one of the eyes is rotated a certain number of degrees inwards or outwards, and starts in all its movements from this position. Since the eyes accompany each other in all movements in the normal manner, the squint is said to be "concomitant."

Concomitant squint may, as already pointed out, result from an original preponderance of the internal or external recti, especially when, owing to a great inequality in the refraction of the eyes, or to impaired vision of one of them, the stimulus to binocular fixation is removed or weakened. Apart from this hypermetropia is the common cause of convergent, and myopia of divergent, squint.

In hypermetropia the retina lies in front of the focus for parallel rays; in order, therefore, that they may be brought to a focus on it, the accommodation must be called into play. If, therefore, the possessor of hypermetropic eyes is to see clearly at any distance, he must use an amount of accommodation in excess of that required by the emmetrope.

It has been stated already that the acts of accommodation and convergence are associated; it is now necessary for us to examine the connection which exists between these more closely, as it is upon this that the pathology of this form of squint depends.

In the normal condition accommodation and convergence always go hand-in-hand. If a pair of normal eyes look at a distant object, the visual axes are parallel, and the accommodation is in abeyance. In proportion as the object is brought nearer, so are more convergence and more accommodation required. From this constant association of the two functions it follows that they can be used together with a less expenditure of nerve force than when either is used alone. Their association is, however, not an absolute one. If a pair of prisms be placed in front of the eyes, with their base inwards, and an object (such as a page of print) be placed at a suitable distance in front of the face, the image will fall on the yellow spot in each eye without any convergence being used, but the accommodative effort required will remain unchanged. In the same way, if convex lenses be used and the object placed at their principal focus, the rays will be rendered parallel, and consequently no accommodation will be necessary, while the convergence will be unaffected. In either case it will be found possible to read for a time, but soon a sensation of fatigue will indicate there is an unusual expenditure of nerve force. If, however, the prisms and lenses are combined, no discomfort is experienced. This association of the two functions is well illustrated by the metrical system of notation. (*See* page 465.) If, for instance, a pair of emmetropic eyes fix an object at 33 cm. ($\frac{100}{33}$) the accommodation is 3 D and the convergence 3 ma.

To the hypermetrope three courses are open: (1) He may not use the necessary amount of accommodation, in which case his vision (and especially his near vision) will be defective; (2) by putting forth extra nerve force he may use the accommodation which is required, in which case fatigue will be experienced after a time; (3) he may use the necessary accommodation, but, to economise nerve force, a corresponding amount of convergence is called into action, and a convergent squint is the result.

At first the excessive convergence is only called into play when the strain on the accommodation is at its maximum (as in looking at a near object); the child soon learns, however, that fatigue can thus be saved, and accordingly soon takes to squinting when looking attentively at any object. The internal recti, now frequently receiving a nervous stimulus, soon preponderate over their opponents (the external recti), and as a result the convergent squint becomes constant.

Although really a binocular affection, concomitant squint always appears to be confined to one eye, for if both eyes deviated inwards to an equal extent, the visual axis of neither would be directed towards an object situated in the middle line, and consequently not only would neither eye see it clearly, but, as its image would fall on non-corresponding parts of the two retinæ at the same distance from the yellow spot, there would be double vision. To avoid this the patient, maintaining the same amount of convergence, turns both eyes to the right or left, so that the one eye fixes its visual axis on the object, while the other takes up the whole of the squint. For instance, if the amount of convergence were such that if the two eyes deviated equally each visual axis would make an angle of 15° with its correct position, then when the one eye fixed the object the other would deviate inwards 30°.

Sometimes it is a matter of indifference to patients as to which eye they use for vision, and accordingly sometimes one eye squints and sometimes the other; under these circumstances the squint is said to be *alternating.* In most cases, however, either from the beginning, or after the squint has existed a short time, the patient uses the same eye always, and the squint is then said to be *fixed* in the other. A fixed and an alternating squint can be distinguished by the following method: The patient is directed to look at an object held a few feet from his face, the eye with which he fixes is then covered with the hand, the one which was squinting immediately moves outwards and fixes the object, while the covered eye takes up the squint; if the squint is alternating (*i.e.* if it is a matter of indifference to the patient which eye he squints with), when the hand is removed the eyes will remain in the position in which they were at the moment of its removal; if, on the other hand, it is fixed, they will return to their original position.

When the squint is alternating, the vision of the two eyes is equal, or nearly so; in fixed squint, on the other hand, the squinting eye is nearly always amblyopic. This amblyopia is unaccompanied by any changes visible with the ophthalmoscope, and has been considered both as the result and as the cause, or one of the causes, of the squint. Until recently the former view was generally held. Since patients with squint do not as a rule suffer from diplopia, it is evident that they must be able to disregard or "suppress," as it is called, the visual impressions transmitted from the squinting eye. Such a power is to some extent physiological. We are in the constant habit of suppressing the images of objects at which we are not looking. Were this not so, we should constantly suffer from diplopia. When, however, the image of an object on which the attention is concentrated falls on the yellow spot of one eye, and on some other part of the retina in the other, the patient finds it difficult to suppress the latter image. Hence when a squint appears suddenly (as in paralysis of one of the ocular muscles), there is always diplopia. In the case of concomitant squint, on the contrary, the object at which the non-squinting eye is looking is not seen by the squinting eye, nor does this eye take cognisance of any other object which may happen to lie on its visual axis. Evidently, therefore, it possesses in a very high degree the power of suppressing images. It has been generally believed till recently that the constant "suppression" of the visual sensations derived from one eye led to changes either in the retina or in nerve centres, which caused the amblyopia. The weak point in this theory is that there are no authenticated cases in which the amblyopia has been known to have come on after the appearance of the squint; but, on the other hand, it may be said in reply to this, that squint usually comes on before the vision can be tested, and that most cases when first seen are treated. Nor is there any good evidence that the amblyopia can to any great extent be remedied by using the eye.

There can be no question that amblyopia of one eye increases the liability to squint by removing the stimulus to binocular fixation, and that a hypermetrope with monocular amblyopia would be more likely to squint than one with the same refraction and no amblyopia. Either theory is consistent with the fact that in alternating squint there is no amblyopia. According to the one theory a squint remains alternating because the eyes are equal; according to the other view the eyes remain equal because the squint is alternating. The writer has no facts of his own which weigh very strongly on either side; he has not unfrequently seen vision of the amblyopic eye improve by practice, but not to any great extent, and it is quite likely that some impairment of vision would result from want of use of the eye, and that this would be remediable. As regards the nature of the amblyopia, if the visual field is tested in a rather dull light, it will usually be found that the central vision is lowered more than the peripheral.

Patients whose squint is alternating, and who consequently have good vision in each eye, generally continue to suppress the image in one eye, even after the squint has been rectified; that this is so can be proved by means of Snellen's coloured letters (described on page 349). When patients are sufficiently intelligent to explain what they see, it will often be found that they can see either set of letters at will, and can change from one to the other without any appreciable interval, and, if the squint has been cured, without movement of the eyes, but that they are rarely able to see all the letters at once.

Another very simple and efficient test of the existence of binocular vision is furnished by Hering's apparatus. (*See* page 460.) Some recent experiments by Dr. Landolt with this have shown that by practice binocular vision can be restored or established in a considerable number of cases.

More facts are required to show to what extent and under what circumstances the amblyopic eye is used. The writer formerly believed that it was used little, if at all; but more recent experiments have convinced him that objects lying on or near its visual axis are sometimes seen first by that eye, although they are immediately afterwards fixed by the other eye. After correction of squint, the amblyopic eye certainly sometimes is used in indirect vision for that part of the visual field which is inaccessible to the sound eye.

While a concomitant strabismus is still only occasional, the treatment consists in counteracting the cause which is producing it, by correcting the hypermetropia with convex glasses, thus rendering the excessive accommodation unnecessary. In the majority of cases in which the squint is still only occasional, and in many in which, although constant, it is alternating, the constant wearing of the correcting glasses will in a few weeks cure the squint, or, prevent it from appearing as long as they are worn, and in time effect a complete cure. Habits acquired in childhood are, however, not always easily unlearned, and the squint will sometimes persist even after the cause which originally led to its production has been removed. The effect of atropine will often give a correct indication as to the probability of curing the squint with glasses. If, when accommodation is rendered impossible by atropine, the visual axes are parallel, the probability is that the squint will be cured by glasses; if, on the other hand, the drug paralyses the accommodation, but has no effect on the convergence, it indicates that the internal recti have gained a preponderance over their opponents, and that the position of rest is no longer parallelism but convergence. The eyes then can only be put straight by an operation which will restore the balance. In old cases, too, the contractility of the external rectus is impaired by the constant stretching to which it is subjected.

Strabismus usually appears between the ages of five and nine, the period being no doubt determined by the age at which the child begins to use the eyes more for near vision, as in reading; occasionally, however, it comes on earlier, and if it makes its appearance before the child is old enough to wear glasses, some doubt may exist as to the best course to pursue. If nothing is done till the child gets older, there is perhaps a risk of the squinting eye becoming amblyopic in the meantime; on the other hand, it is difficult to regulate the effect of an operation with accuracy in so young a child. As long as the squint remains alternating, there is no objection to waiting; when it has become fixed, it is a good plan to cover the fixing eye for several hours a day, and to make the child use the other. If, as is frequently the case in young children, this is not practicable, the internal rectus should be divided.

In older children when the squint is only occasional, when it is alternating, and when it diminishes under atropine, spectacles should be prescribed in accordance with the principles laid down in chapter xiii., and directions given that they should be worn constantly, care being taken that they are so fitted that the child cannot look over or under them. If after a few weeks' trial the squint remains unaffected, or if it has been considered useless to try glasses, division of the internal rectus should be resorted to. In any case the glasses to correct the hypermetropia should be worn after the operation.

In operating for squint the aim of the surgeon should be to divide the tendon of the muscle as close to its insertion as possible, but to avoid disturbing the little tendinous fibres which, passing from the borders of the tendon to the capsule of Tenon, establish an indirect and loose connection between the muscle and the globe. If any fibres of the muscle remain undivided, they will completely nullify the effect of the operation; if, on the other hand, the parts are freely disturbed, or if the muscle be divided too far from its insertion, the proximal end contracts a new adhesion far back on the sclerotic, or becomes adherent to its sheath, and in either case the action of the muscle is so much weakened that divergence of the eye takes place sooner or later, a result which is still more likely to ensue if the eye is amblyopic. If, owing to the great amount of the convergence, a considerable effect is required, the surgeon should endeavour to produce it by operating on both eyes, and not by a great weakening of the internal rectus of one, which must of necessity place that eye at a disadvantage as compared with the other. It should always be borne in mind that for perfect vision the two eyes must move in concert.

The surgeon stands on the patient's right and facing him, and the eyelids having been separated by a spring speculum, he pinches up a fold of conjunctiva at the point of meeting of the inner vertical and lower horizontal tangents of the cornea (if the forceps are opened wide enough and pressed slightly on the globe, Tenon's capsule will be seized at the same time); the fold thus raised is then divided with a pair of blunt-pointed scissors (Fig. 88 or 89); the incision should be no longer than will suffice to admit the hook and the blades of the scissors for a distance of about 15 mm., and need therefore never exceed 5 mm. (its direction should be vertical, or inclined downwards and outwards). If the capsule of Tenon is not divided in the first cut, it must be picked up separately and divided in the same manner as the conjunctiva.

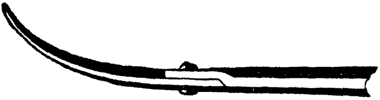

Fig. 88.—Curved Strabismus Scissors.

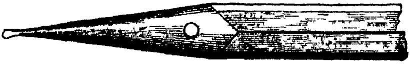

Fig. 89—Straight Strabismus Scissors.

The next step in the operation is to pass the strabismus hook beneath the muscle. Its point should first be carried downwards a short distance to insure its passing beneath the lower border of the muscle; it is then guided upwards beneath the muscle, following the convexity of the globe, of which its point should never lose touch, until the latter can be seen

Fig. 90.—Strabismus Hook.

beneath the conjunctiva above the upper border of the muscle; the hook should now be drawn forwards towards the cornea. If it has passed beneath the muscle its forward passage will be checked by the attachment of the latter to the sclerotic; if, on the contrary, the muscle has been missed, it can be brought right up to the corneal margin. The latter accident may happen either from the point not having been at first carried far enough in the downward direction, or from Tenon's capsule having escaped division; when it occurs, a second attempt to pass the hook should be made, and, this failing, the capsule of Tenon must be divided. In passing the hook beneath the muscle, there should be hardly any sense of resistance; if there is, it generally indicates either that its point has caught in a fold of Tenon's capsule, or that it still lies superficial to that structure. The passage of the hook being completed, the operator transfers the instrument to the left hand, and, slightly relaxing the traction on it, introduces the scissors on the side nearest to the insertion of the tendon, one blade being passed beneath the tendon and the other immediately beneath the conjunctiva; its passage is facilitated if the tendon be drawn slightly away from the globe with the hook. The tendon is divided by one or two snips; as soon as its division is complete the hook comes forwards to the cornea. The operation should now be complete, but it is as well to re-introduce the hook, in case any fibres should have escaped division.

As soon as the muscle is divided, the tonic contraction of the external rectus rotates the globe somewhat outwards; a gap is consequently left between the divided ends of the tendon, and this is still further widened by the contraction of the proximal end of the divided muscle. The result is that the tendon does not extend so far forwards on the sclerotic as its original point of insertion by about 5 mm., and it becomes adherent in this new situation. If any fibres of the tendon remain undivided, they will completely nullify the effect of the operation by preventing the retraction of the muscle ; if, on the other hand, the connections of the tendon with Tenon's capsule are severed, the retraction of the muscle, which they would otherwise limit, is very great, and leads to the new insertion being placed very far back on the globe. The effect of the operation is therefore twofold: in the first place, there is an immediate improvement in the position of the eye, owing to its being rotated outwards by the external rectus; and, in the second place, the shortening of the internal rectus somewhat curtails the extent of its action.

This weakening of the action of the muscle places the eye at some disadvantage as compared with its fellow; hence it is better when possible to divide the operation between the two eyes, putting back the attachment of the muscle to an equal extent on the two sides.

Generally it is better that there should be an interval before the second eye is operated on; but if, after complete division of one tendon, there is still considerable convergence, it is almost certain that there will be more when the patient recovers from the anæsthetic, and the second eye may therefore be operated on at once. Occasionally some convergence remains even after both internal recti have been divided ; in such cases the internal rectus of the eye which appears to be most affected may be again divided. The surgeon, however, in such a case, should be especially on his guard against being tempted to do too much, since it not unfrequently happens that cases which have been operated on several times with very little effect suddenly pass into divergence; it is possible that in such cases the normal relations between Tenon's capsule and the ligamentous filaments from the tendon have been disturbed, and the latter divided in the last operation.

When it is suspected at the time that the effect of an operation has been too great, a conjunctival suture should be introduced over the internal rectus, pinching up a fold of conjunctiva, for the shortening thus produced limits to a certain extent the retraction of the muscle.

When the remaining convergence is only slight, the correcting glasses should be worn continuously for a few weeks before a further operation is resorted to.

Now that cocaine has come into use as a local anæsthetic, general anæsthesia may be dispensed with, except in the case of young children. The drug appears, however, to have little or no action on parts with which it does not come into actual contact; hence merely dropping into the conjunctival sac does not render the muscle anæsthetic. The latter object can be attained by injecting about 5 mm. of a 5 per cent. solution beneath the conjunctiva in the neighbourhood of the muscle to be divided.

Divergent strabismus, when not due to paralysis or division of the internal rectus, may depend upon a congenital preponderance of the external over the internal recti, coupled with the loss from any cause of binocular vision, or upon myopia. Its connection with the latter condition is analogous to that which exists between hypermetropia and convergent strabismus; for while in hypermetropia the patient has always to use an amount of accommodation in excess of that required by a normal eye, and therefore uses at the same time the associated act of convergence, the myope always uses less accommodation than the normal eye, and consequently finds it easier to use less convergence. There are, moreover, other causes which induce divergence in high degrees of myopia; for, as all objects have to be held very close to the eyes, the amount of convergence required to maintain binocular vision would be actually very great, besides being in excess of the accommodation. In high degrees of myopia, too, the globe has no longer a spherical, but an elliptical form, which is not nearly so well adapted for rotation. In these cases the patient usually holds his book, not in the middle line, but opposite one eye. As regards treatment, the choice will lie between division of one or both external recti, advancement of the insertion of the internal rectus of the diverging eye, or a combination of these proceedings. Division of the external rectus does not produce nearly so great an alteration in the position of the eye as does that of the internal, possibly because, its insertion being farther back, it is not permitted by its attachments to the capsule to retract to so great an extent, and also in many cases because the power of the internal rectus is defective. Consequently this proceeding is only adapted for very slight cases of divergence. The operation of advancing the internal rectus consists essentially in detaching the tendon from the sclerotic, and uniting it to the subconjunctival tissue at a point nearer to the cornea, the muscle being at the same time shortened if necessary. That the operation, in the hands of many, has proved troublesome to perform or unsatisfactory in its results is shown by the variety of ways in which its details have been modified. The following seem to be the chief difficulties which have been experienced : In the first place the muscle may slip from the surgeon's grasp before a suture has been passed through it, and as it is naturally of small size, and often atrophied from disuse, it is sometimes very difficult to find again ; then the suture which is used to secure the muscle in its new situation occasionally gives way before the new attachment has become consolidated ; finally, it is always extremely difficult, and often impossible, to form a correct estimate of the effect of the operation while the patient is still under the influence of an anæsthetic. Nothing would be gained by enumerating the various modifications which have been made in the details of the operation in order to avoid these difficulties, for it is eminently an operation which every surgeon will modify in some minute point to meet the difficulty which to him appears the most prominent. The following operation, which is a slight modification of that suggested by Dr. Prince, of Philadelphia, is one that the writer has found to answer well: The operator fixes on the point for the new attachment of the tendon; he then seizes a horizontal fold of conjunctiva having its centre over this, and transfixes its base in a direction parallel to the edge of the cornea, with a needle carrying a ligature of which the two ends are equal, care being taken to pinch up and transfix the subconjunctival tissue as well. A conjunctival incision is next made, as in the ordinary operation for squint, and a hook passed beneath the muscle; if Wecker's double hook (Fig. 91) is at hand, one limb is passed under the muscle and the other is firmly pressed down on it above the conjunctiva, so that the tendon and conjunctiva are firmly gripped. If this hook is not available, a pair of small straight forceps may be used, one blade being guided by the hook beneath the tendon, while the other lies above the conjunctiva; the muscle, being thus securely held, is divided with the conjunctiva as close as possible to its insertion; it

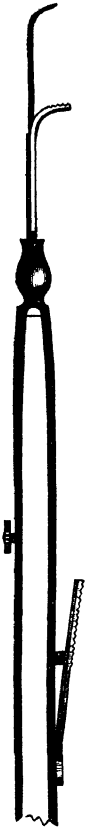

Fig. 91.

is then held away from the globe, and thoroughly freed from all attachments which may exist between it and the globe. The needle attached to the suture is now taken and passed through the conjunctiva and the upper border of the muscle from without inwards, well behind the point where the muscle is held (the greater the effect desired the farther back must the suture be carried); it is then passed from within outwards, close to the lower border. If the ends of the suture were united, we should now have a continuous double thread forming a rectangular figure, of which the vertical sides are situated beneath the muscle, and the subconjunctival tissue at the point of intended attachment, the horizontal sides lying above the conjunctiva. Before tightening and tying the suture, the external rectus is divided, and the internal rectus and conjunctiva over it shortened by dividing them on the proximal side of the hook, which is thus detached. Opposite ends of one of the sutures are then seized, drawn tight, and tied, the muscle being thus drawn forwards. If the patient is under an anæsthetic it will be well to leave the second suture, so that the effect of the operation can be increased or diminished by its aid if necessary. Mr. Prince's operation differs from that just described, in the fact that the subconjunctival suture adjacent to the cornea, and the muscular suture are distinct; the former is tied over one end of the latter in a loop which allows it to glide to and fro; when the ends of the muscular suture are tied and tightened, it is thought that this pulley arrangement thus provided allows the effect to be easily regulated. If the effect is not that which is desired, the second suture can be tied the next day. If silk be used, it should be rendered supple and aseptic by soaking it in a solution made by mixing one part of salicylic acid, one part of glycerine, and nine of alcohol; cocaine usually produces sufficient anæsthesia.

It was formerly the custom to attempt to keep the eye rotated inwards after the operation by a suture fixed to the side or bridge of the nose; it is, however, difficult in this way to produce a satisfactory rotation, and if the patient does make any sudden attempt to rotate the eye outwards, there would be a risk of the sutures being torn through. It is a good plan to keep both eyes bandaged for a few days, so that the risk of movement may be reduced to a minimum.

M. de Wecker has devised a modification of this operation, which he calls capsular advancement. In it both Tenon's capsule and the tendon are drawn forwards, the latter being folded on itself. The first stage consists in passing sutures in a horizontal direction through a fold of conjunctiva above and below the cornea, the needle in each being towards the muscle to be advanced. An incision is then made below the muscle, as in the ordinary squint operation, and the hook is passed beneath the tendon; the point of the hook is now exposed by a similar incision above the upper border of the muscle. The hook being raised, the scissors are passed well beneath the muscle to free it thoroughly, and the capsule is freed from its upper surface; each needle is then taken, and, having been entered through the corresponding opening in Tenon's capsule, is carried backwards to an extent depending upon the effect required, and brought out through muscle, capsule, and conjunctiva. The two ends of each suture are then tightly drawn and tied, the opponent rectus being first divided if it is thought desirable. I have performed this operation a good many times, and am well satisfied as to the correction that can be obtained by it. There is often, however, a mass of granulations, or of folded conjunctiva in the region of the suture, which is trouble some for a long time.

For the result of an operation for squint to be perfect, not only must the visual axes be parallel, and the movements of the eyes be equal, but there should be binocular vision. When, as is frequently the case, there is a considerable degree of amblyopia in the eye which squinted, this result cannot, of course, be attained, and under these circumstances, although perfect parallelism may be secured at the time, divergence of the amblyopic eye is very apt to ensue. Unless the amblyopia is amenable to treatment, it is well to leave a very slight degree of convergence in such cases, which should not be sufficient to interfere with the cosmetic effect.

Affections of the intra-ocular muscles.—There are three distinct muscles within the eye: the constrictor of the pupil, its dilator, and the muscle of accommodation. The sphincters of the iris and the ciliary muscle are supplied by filaments from the third nerve, which pass through the lenticular ganglion; the dilator muscle by the sympathetic, some of the fibres of which pass through the ganglion, while others, it is believed, pass to the iris without being connected with it.

The movements of the pupil are influenced by a great many circumstances, which it is beyond our province to discuss fully here. Any influence which excites the vaso-motor nervous system may cause dilatation of the pupils (*e.g.* cutaneous irritation, sudden fear, etc.). Contraction of both pupils is induced by light falling upon either retina, or in association with an effort of convergence or of accommodation; the connection of pupillary contraction with convergence being more intimate than with accommodation.

The mean condition of the pupil varies much in different individuals, and in the same individual at different periods of life, becoming smaller with increased age, the pupils of aged people being sometimes extremely minute.

The afferent impulse which leads to contraction of the pupil is conveyed by the optic nerve to the corpora quadrigemina, whence it is transferred to the centre in the floor of the aqueduct of Sylvius, which is the origin of the motor fibres. If therefore light, falling upon the retina of one eye, induces contraction of either pupil, it is a proof that the conductility of the optic nerve fibres is present in the eye on which the light impinges (but not necessarily that the subjective sensation of light exists). If under such circumstances one pupil fails to contract, and no mechanical obstacle is present (such as iritic adhesions or spasmodic contraction of the radial fibres), its motor nerve is at fault. If neither pupil acts, and the power of conduction in the optic nerve is proved by there being perception of light, there is a break in the path of transferrence from the sensory to the motor centre, (as is the case in locomotor ataxy), or the motor centre itself or the filaments from it are at fault, when the associated movements will also be lost.

Certain drugs act upon one or the other set of fibres. Mydriatics produce dilatation of the pupil by paralysing the sphincter (atropine, homatropine, duboisine, etc.), or by irritating the sympathetic filaments and causing the radial fibres to contract (cocaine). With the exception of cocaine, all known mydriatics paralyse also to some extent the ciliary muscle. Myotics produce contraction of the sphincter and ciliary muscle by irritation of the filaments of the third nerve, or by acting directly upon the muscular tissue.

Cases are occasionally met with in which the functions of these muscles are impaired in various ways. Thus there may be paralysis of all the muscles (ophthalmoplegia interna), the iris may be affected alone (iridoplegia), or the ciliary muscle alone (cycloplegia).

Ophthalmoplegia interna may affect one or both eyes; usually it commences in one eye and subsequently attacks the other. The pupil of the affected eye is of medium size, and varies neither under the influence of light and shade, nor in association with convergence; as a rule, however, mydriatics and myotics act as in the normal state.

These cases are rare and run a very chronic course, the iris of one eye being at first only sluggish in action; gradually the impairment of movement becomes greater, and affects the other eye also. Sometimes the external muscles subsequently become affected, those supplied by the third nerve being the first to suffer. (*See* ophthalmoplegia externa.)

From the fact that these symptoms commonly affect both eyes, and that they are apt to occur in association with ophthalmoplegia externa, which is known to depend upon degenerative changes in the nuclei of origin, it is probable that the lesion here is also nuclear. The fact that the nuclei which respectively control the ciliary muscles, the circular and radiating fibres of the iris, the act of convergence, and the origin of the other muscles supplied by the third nerve, are in close relation to each other and lie in the order enumerated from before backwards, is also consistent with this view.

In most cases of ophthalmoplegia interna there is a history of former syphilis; sometimes it occurs as an early symptom of locomotor ataxy. The progress of these cases is usually slow, but they vary a good deal in this respect. The writer has for three years seen at intervals a man apparently in perfect health who has had total ophthalmoplegia in one eye and a sluggish pupil in the other during the whole time; no history of syphilis can be obtained, and the only other symptom pointing to the possibility of commencing locomotor ataxy is the complete absence of knee reflex. Paralysis of the accommodation is an occasional sequela of diphtheria, but the sphincter usually escapes. W. A. F.

CHAPTER XV.

AFFECTIONS OF THE ORBIT.

AFFECTIONS of the orbit are of importance, not only because they may implicate the eye, but also because they may endanger life.

The globe is supported in the orbit by its muscles, by the cushion of adipose tissue behind it, and by offshoots from Tenon's capsule, especially a band, which, passing like a sling beneath it, is attached to the margin of the orbit on either side, thus forming a suspensory ligament.*

Any rapid increase of the contents of the orbit may cause compression of the optic, motor, or sensory nerves, and may be relieved by the globe being pushed forwards; but this may itself cause atrophy of the optic nerve from the traction, or sloughing of the cornea from exposure.

The danger to life arises chiefly from the intimate connection which exists between the cranial and orbital cavities. Above, they are separated merely by a thin plate of bone, except in front, where the frontal sinus intervenes, and inflammation arising in the periosteum on the one side readily produces inflammation of the dura mater on the other. Posteriorly they communicate through the sphenoidal fissure and the optic foramen; veins pass through the former to communicate with the cerebral sinuses, while through the latter the sheaths of the optic nerve are directly continuous with the meninges of the brain.

Cellulitis and abscess.—That cellulitis of the orbit is not more common is probably owing to the fact that its cellular tissue is nowhere directly continuous with that of the rest of the body, being inclosed on four sides by bony walls, while in front it is separated from the cellular tissue of the face by the palpebral ligament, which, although only a thin membrane, checks the spread of slight inflammation from the eyelids into the orbit.

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* Lockwood, "Muscles and Fasciæ of the Orbit." 1885.

Cellulitis may be induced by wounds in which the cellular tissue is opened, by the spread of inflammation from adjacent parts (as when it occurs as a complication of facial erysipelas or gonorrhœal ophthalmia), or it may occur in pyæmia and allied conditions, being especially frequent in puerperal diseases and in glanders. It not unfrequently is associated with periostitis of the orbital walls. It may be acute or chronic.

Acute cellulitis is ushered in by severe constitutional disturbance, general malaise, dyspepsia, high temperature, and frequently with rigors. There is pain, at first dull, but rapidly increasing in intensity, in the course of distribution of the first division of the fifth nerve, and this persists either until the inflammation subsides, which rarely happens, or until pus has formed and has made its exit. At the same time the eyelids are usually of a dusky red colour and much swollen, and the conjunctiva is injected and swollen, forming a prominent wall around the cornea. When this is the case, there is great risk of the cornea sloughing from compression of its nutrient vessels, a result which may almost certainly be predicted if it is at the same time anæsthetic from pressure on the ciliary nerves. If the finger can be passed a slight distance into the orbit, between the globe and the roof, an irregular elastic swelling can usually be felt. The globe is usually slightly prominent, and may be extremely so, and its mobility is always impaired. The latter symptom may be due simply to the pain caused by the disturbance of the inflamed tissue when any attempt at movement is made, or to pressure on the muscles or their nerves by the products of inflammation. In most cases the natural mobility of the eye is restored when the pus has been evacuated. In a few fatal cases, however, adhesions have been found between the globe and Tenon's capsule, and between individual muscles and their sheaths; and in others the tissue of one or more muscles has been found to have been completely destroyed.

Vision may be seriously impaired or destroyed, independently of any corneal affection, either by direct pressure on the optic nerve, or by the extension of the inflammation to its interstitial tissue. A complication which is more rare, or more rarely recognised, is detachment of the retina, due probably to effusion of fluid in consequence of the obstruction to the circulation. If the cornea slough, suppuration will usually be set up within the globe; but a suppurative inflammation of the uveal tract may occur independently of any corneal lesion, and is not uncommon in pyæmic cases.

The progress of acute cellulitis is nearly always to suppuration, although a sufficient number of cases have been recorded to prove that a very acute inflammatory œdema of the orbital cellular tissue may end in resolution. The pus usually makes its way forwards, the eyelids become more tense, and the abscess points either in the upper or lower lid (usually the former), near the margin of the orbit.

Occasionally the pus makes its exit through the conjunctiva, between the insertions of two of the recti, and may in such a case appear at first sight to come from within the globe. Unfortunately the extension occasionally takes place in the opposite direction, the pus passing through the sphenoidal fissure into the spheno-maxillary or zygomatic fossa.

During the course of the inflammation, and probably in pyæmic cases at the outset, the orbital veins may become implicated, and the phlebitis extend to the cavernous sinus; it seldom stops short here, but commonly passes across to the sinus on the opposite side, or extends to the cerebral veins or to the other sinuses, and downwards to the internal jugular veins, such cases being usually fatal from encephalitis or pyæmia. The effect of the cavernous sinus on the opposite side being involved is that that eye also becomes prominent. If during an attack of cellulitis this occurs, and at the same time cerebral symptoms are developed, phlebitis of the cavernous sinus may be diagnosed almost with certainty.*

Periostitis of the walls of the orbit is a not unfrequent complication of cellulitis.

If there are no complications, and the pus is evacuated early, the prognosis of acute cellulitis is fairly good. The danger to life is from implication of the brain or its membranes; to vision, from sloughing of the cornea, atrophy of the optic nerve, or suppurative inflammation of the eyeball. It is of the utmost importance therefore to afford an exit for the pus as soon as possible. If fluctuation is present, its situation will indicate that in which the incision should be made. If none can be made out, but there is a reasonable probability that pus is present, an exploratory puncture should be made with a narrow knife above the globe (through the conjunctiva when possible), the blade being passed backwards parallel to the roof of the orbit; if, on rotating it slightly, pus escapes, the incision should be cautiously enlarged. Frequently, owing to the swelling, the eyelid cannot be raised sufficiently for the knife to be entered through the conjunctiva, and it must then be passed through the upper lid close to the margin of the orbit; and the same proceeding should be adopted if there is any reason to suspect that the periosteum is implicated; indeed, although the conjunctival incision presents certain advantages over the cutaneous, in practice it can seldom be made.

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* Graefe-Saemisch's Handb. vi. xi. 539. Berlin.

The relief afforded by the evacuation of the pus is generally immediate, the local and general symptoms rapidly subside, and, if vision has been impaired only from moderate pressure, complete recovery may be looked for. As the suppuration diminishes, the cavity gradually fills up from below, and the wound soon closes; occasionally, however, a fistulous opening persists, although this is less common in the acute than in the chronic cases. It is in order to avoid the formation of such a fistula that we make the incision, when possible, in the conjunctiva, for not only is the fistula unsightly and a nuisance to the patient while it remains open, but when it heals the lid is often drawn in and otherwise distorted by the contraction of the cicatricial tissue.

It is generally futile, and often injurious, to endeavour to check the inflammation by so-called antiphlogistic remedies; the affection is often directly connected with pyæmia and erysipelas, and even when it is not so, it indicates a condition of lowered vitality. Relief to pain may sometimes be temporarily procured by local abstraction of blood in small quantities, or by the application of cold; but both remedies should be used sparingly, and be combined with general tonic treatment.

Cases of orbital suppuration occur, which would perhaps be best described as subacute; in these the suppuration is limited, and the general symptoms are absent or trivial. There is one local symptom, however, which is seldom absent, namely, a vascularity and œdematous swelling of the conjunctiva, limited to a single region, and extending perhaps over a quarter of the circumference of the globe; I have, however, recently seen a case in which this was present, but in the symptoms entirely subsided without suppuration taking place.

Chronic cellulitis of the orbit is not often met with in other than scrofulous subjects, and in them is commonly associated with diseased bone or periosteum, a slight injury, or the presence of a foreign body.

The symptoms are less marked, and the diagnosis consequently less easy, than in the acute cases. It generally runs on to suppuration, but it does so slowly, and the pus may remain for a long time within the orbit before it makes its way to the surface. Chronic cellulitis and chronic abscess are but different stages of the same affection, and the boundary line between them is not well defined.

Before suppuration has taken place, the difficulty consists in diagnosing between cellulitis and periostitis. The two affections are often present together; but when a chronic localised periostitis exists uncomplicated with inflammation of the cellular tissue, there is generally localised tenderness of the orbital walls, the pain is aggravated at night, and there is less œdema of the lid than is the case in cellulitis. After suppuration has taken place, the diagnosis has to be made between cystic and soft solid tumours and chronic abscess. The only point by which the abscess can be distinguished is the presence of inflammatory symptoms; but these may have subsided before the patient comes under observation, and œdema of the lids is sometimes present in cases of orbital tumour, in consequence of the circulation being impeded. The only means of establishing the diagnosis with certainty consists in making an exploratory puncture, and this should always be done.

The presence of pus having been ascertained, it should be evacuated by a free incision, and a careful examination made to ascertain the condition of the bone, which is often carious.

It is in these chronic cases that the formation of a fistula is chiefly to be feared. In healing, they are very apt to cause contraction of the integuments and palpebral ligament, and may thus produce complete eversion of the lid. The tendency to contraction must be combated by a careful dressing, and in some cases it may be desirable to prevent deformity of the eyelid that is implicated by uniting it temporarily with the other; for this purpose the edges of the eyelids are made raw by removal of a narrow strip of skin just posterior to the eyelashes, stopping short a little to the outer side of the lacrymal puncta, and the opposed edges united with a few sutures; when all danger of contraction is passed, the lids are easily separated with a director and a bistoury. The tendency of the opening to become fistulous must be met by keeping the orifice open, and ensuring free drainage, so that the deeper parts may heal before contraction of the orifice takes place. No doubt also the adoption of antiseptic precautions from the commencement, or rendering an existing sinus aseptic when possible, tends to prevent that prolonged suppuration which is so frequently a cause of intractable fistulæ. These will remain, however, notwithstanding all precautions, in a certain proportion of cases.

In order to avoid the formation of any visible fistula, it was proposed by M. Riberi * to make the pus find its way into the nasal fossæ through the infundibulum when the abscess is on the inner side of the orbit. With this object an incision is made through the upper lid, and the pus evacuated; the os planum of the ethmoid is then exposed, and broken away with a chisel and mallet (an opening being made sufficiently large to admit the point of the finger), and the

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* Demarquay, "Tumeurs de l'Orbite."

external wound is closed. If the inner wall of the orbit were carious, an operation of this nature might perhaps be justifiable, but in any other circumstances it would appear to be bad surgery, for it aims at preventing the possible formation of a sinus in an accessible situation by the certain production of suppuration in a sinous canal which opens in an inaccessible position by a narrow orifice, and the production of a compound fracture is an essential part of the operation.

Periostitis, necrosis, and caries.—Periostitis may be either acute or chronic. The acute cases vary in severity from a localised inflammation which leads to the formation of a subperiosteal abscess, and possibly a limited necrosis, to a diffuse suppurative periostitis of a large portion of the orbital wall, which runs on rapidly to necrosis, and may set up fatal mischief in the brain or its membranes.

Acute localised periostitis commences with deep-seated pain in the orbit radiating along the branches of the first division of the fifth nerve. There may be marked general symptoms, as elevation of temperature and loss of appetite, and the eyelids become puffy and the conjunctiva injected, while within the orbit an acutely tender swelling can often be felt by pressing the finger against the orbital wall. The eyeball is fixed, and may be displaced by the swelling. If the pus be evacuated, the general and local symptoms rapidly subside, unless, as frequently happens, the bone has become necrosed. Such localised periosteal abscesses are, however, by no means free from danger if they are situated on the roof of the orbit. Several instances of this kind have been recorded in which symptoms, looked upon at first as trivial, have suddenly been complicated by the onset of delirium, quickly succeeded by coma and death, and the post-mortem has revealed suppuration between the dura mater and the bone, an abscess in the anterior lobe of the brain, or general meningitis.

Diffuse suppurative periostitis is a much more formidable affection. The local symptoms consist in deep-seated and radiating pain, prominence and immobility of the globe (the conjunctiva of which is much injected), and great swelling of the lids and surrounding integument. They differ therefore only in degree from those which are present in the localised form. It is the severity of the general symptoms that constitutes the characteristic feature of these cases; these are sometimes so pronounced as to cause the importance of the local condition to be overlooked. They consist of elevated temperature, intense headache, and delirium, the latter, at first, only at night, then constant, and passing into coma. The following case illustrates the symptoms and pathology of this affection:

"A boy, aged 15, complained of swelling of the right cheek and pain in the teeth. After a few days the pain passed to the left side of the head, and affected the left eye. Then irregular attacks of fever with insomnia and loss of appetite occurred, and on the seventh day violent delirium set in. On the eighth the upper lid was much swollen, the eye injected and somewhat prominent, and nausea, intense headache, and moderate fever were present. By night the swelling had extended to the forehead, and there was delirium. The following day the patient was delirious throughout; on the twelfth day coma supervened and was followed by death. At the post-mortem the cellular tissue of the orbit and the integuments were found to be infiltrated with pus, the frontal bone was denuded and carious in its whole thickness nearly up to the level of the hair. The posterior and inferior part of the orbital wall was also carious. The dura mater was detached from the vertical plate of the frontal bone to the same extent as the periosteum, but was still adherent to the roof of the orbit. The arachnoid was coated with puriform lymph. The brain substance appeared healthy." *

The prognosis of acute periostitis, as regards life, is favourable if the disease is limited in extent and does not affect the roof of the orbit; necrosis, however, is very common. In the severer cases, in which the inflammation involves a large area of the periosteum, and the general symptoms are severe, the prognosis is very grave.

The treatment imperatively demanded in all cases of acute periosteal abscess is to make an incision and release the pus. No surgeon would hesitate to do this in a case of acute periostitis of a long bone, and how much more urgently is this treatment called for when the pus, bound down on one side by the unyielding periosteum, is on the other only separated from the cranial cavity by a thin plate of bone! No harm can be done by making an incision before pus has formed; fatal mischief may ensue if it be delayed too long.

Chronic periostitis is much more common than the acute variety. It may be due to syphilis, scrofula, or, more rarely, to rheumatism; while an injury is frequently the assigned, and occasionally the true, cause.

As a rule it is the forepart of the orbit that is affected, the first symptoms being pain, which is deep-seated and generally aggravated at night, œdema and redness of the lids, and thickening and tenderness just within the orbital margin. If the seat of the inflammation is far back, beyond the reach of the finger, the diagnosis may be difficult; but even in these cases pressure on the wall of the orbit generally gives rise to intense pain, and there is nearly always paralysis of several of the ocular muscles. If, combined with these symptoms, there are aggravation of the pain at night and a history of syphilis, the diagnosis of periostitis may safely be made.

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* Demarquay, "Tumeurs de l'Orbite," p. 35.

While still in the early stage, periostitis may subside, either leaving no trace, or some thickening of the bone, which may be sufficiently pronounced to form a node; or the subperiosteal effusion may suppurate, with or without caries of the subjacent bone.

In the syphilitic cases suppuration is rare, and caries less common than in the scrofulous; while paralysis of the third or sixth nerves is often present. The symptoms may entirely subside, but relapses are very liable to occur, and subsequent attacks always leave some thickening; the latter may lie entirely in the substance of the periosteum, or may form a soft gelatinous subperiosteal swelling, consisting of round granulation cells (periosteal gumma); or the subperiosteal effusion may remain fluid an indefinite time, consisting of either pure pus, or of a reddish serum containing leucocytes. Granulations may spring up from the bone which participates in the inflammation, and a layer of new bone be thus formed, which may vary from a slight thickening to a prominent bony nodule.

Syphilitic periostitis is very amenable to treatment by iodide of potassium and mercury, and even considerable indolent swellings may disappear under their influence. Some years ago Mr. Carter had under his care at St. George's Hospital a case of supposed bony tumour of the orbit, which entirely disappeared under a course of iodide of potassium, and a similar case has been published by Mr. Hamilton.*

Scrofulous periostitis usually affects the margin of the orbit, and nearly always leads to suppuration and caries. The earliest symptoms are generally redness and œdema of the eyelid; after a time fluctuation becomes perceptible, and, the abscess having opened, the bone is found to be denuded, rough, and spongy. The opening does not close, but its margins become inverted and adherent to the periosteum, and when at length it does heal, contraction takes place and an ectropion is produced.

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* *Dublin Medical Journal*, vol. ix. p. 265.

If seen in the early stage, before suppuration has taken place, the treatment must consist in good diet, tonics, and, when possible, residence at the seaside; in very chronic cases the effect of painting iodine over the affected part should be tried. The treatment of the later stage will be better considered under that of caries.

In rheumatic periostitis the inflammatory symptoms are slight or absent, there is little or no subperiosteal effusion, but the pain is severe, and increased in damp weather. It may lead to thickening of the bone or periosteum, but not to suppuration. The treatment will consist in the free administration of iodide of potassium, with which salts of salicylic acid may be combined.

Caries and necrosis.—Caries and necrosis have several times been incidentally referred to in the preceding pages, and the pathology of these affections may be inferred from what has been said.

The most usual situation for caries is the margin of the orbit, and perhaps it is more common at its lower and outer part than elsewhere. Marginal caries usually occurs in scrofulous children, and is often attributed to a slight injury. The symptoms consist in the formation of an abscess in the lid over the affected spot; this bursts and discharges a thin, unhealthy looking pus, the opening contracting into a fistula. This continues to discharge for weeks or months. The orifice generally presents a little button of prominent granulations, and if the probe be insinuated into the sinus it impinges on roughened and softened bone. These cases are extremely chronic; the area affected is not as a rule extensive, but the bone shows no tendency to assume a healthy action unless the patient's general health can be greatly improved by good diet and healthy air, the two conditions which it is difficult to obtain for prolonged periods for patients of the hospital class, from which these cases are for the most part drawn.

If the area affected is of only limited extent, an attempt should be made to dissolve and remove the dead bone, and to set up a healthy action by the application of sulphuric acid (one part of the pure acid to two of water) by means of a glass pipette. If, however, a large area is affected, this method is too slow, and it is difficult to control the action of the acid when applied over a large surface which cannot be very thoroughly exposed. In such cases the only plan which has any chance of success is to remove the diseased bone with the gouge. It is useless, however, to undertake an operation of this kind unless the patient's health is good; otherwise the bone immediately surrounding the carious portion, which is almost necessarily somewhat contused during the operation, will take on a similar action. It is perhaps hardly necessary to point out that when the roof is affected, any gouging operation must be conducted with the greatest caution, and can hardly be undertaken at all with safety if the affected area extends far back; it should be recollected also that, although in the adult the frontal sinus separates the front part of the roof from the cavity of the cranium, in the child this sinus is undeveloped.

In these cases of caries of the roof, which are unsuited for operation, a very guarded prognosis should be given, and the case be kept under observation for a considerable time, as cerebral symptoms may appear after many months, as in the following instance:

"A girl, aged four, fell and struck her eye against a chair; ecchymosis of the upper lid appeared, and later on the globe became prominent, and there was inability to rotate it outwards. The proptosis increased and febrile symptoms came on. An incision was made along the superior border of the orbit, a quantity of serous pus evacuated, and caries of the roof discovered by the probe. The wound healed; but some months later, after an attack of scarlet fever, it reopened and discharged pus and cerebral matter. The child died, and at the post-mortem extensive caries of the roof was found, and a perforation through which the pus in the orbit communicated with an abscess in the anterior lobe of the brain."*

Necrosis of the orbit probably does not occur except as the result of acute periosteal abscess, or of comminuted fractures, in which fragments have become detached from the periosteum. In cases of lacrymal stricture the misdirected and ill-regulated zeal of the surgeon has sometimes caused the bone at the inner angle of the orbit to become denuded of periosteum. The bone, however, is here extremely thin, and receives some of its blood supply from the opposite surface; hence this accident is not, as a rule, followed by exfoliation. The treatment will be that which is proper for necrosis of other bones, namely, to remove the dead portion as soon as it is sufficiently loose. It never becomes invaginated by new bone; at the most a little of the latter is heaped up round its edges, and does not interferé with its removal.

Tumours of the orbit.—It is often difficult to diagnose the presence of a tumour within the orbit, and still more frequently only a conjecture can be made as to its nature. This arises from the fact that the chief symptoms are common to any condition which causes an increase in the contents of the orbit, and that the greater part or the whole of the growth is usually beyond the reach of digital examination.

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* Arch. f. Ophthal., 1855.

If situated far back, among the earliest indications of its presence are displacement and impaired mobility of the globe.

A very fair estimate of the amount of prominence can often be obtained by the surgeon standing behind the patient and looking down on his closed lids. In order to measure the displacement more accurately the surgeon may hold a straight body, such as the edge of a card, across the bridge of the nose, while the patient looks straight forwards; the distance of each cornea from the card can then easily be seen and measured. The lateral displacement can be found by comparing the measurements between the middle line of the face and the centre of the cornea on the two sides. It must be seen, however, that the affected eye is looking straight forwards, and that the centre of the cornea is not merely displaced from rotation of the globe. Displacement of the globe forwards, without impairment of its mobility, does not as a rule indicate the existence of an orbital tumour. These cases of proptosis are referred to in another chapter. A tumour within the orbit may impair the movements of the globe either by direct pressure or by implicating individual nerves or muscles; and sometimes there is at the same time evidence of pressure on the optic nerve, as shown by swelling of the optic disc, and distension and tortuosity of the retinal veins.

The above symptoms give no indication as to the nature of the tumour, and unless some portion of it is within reach of the finger the diagnosis must remain very uncertain. When the growth can be felt, the surgeon should endeavour to ascertain whether it is solid or fluid, whether it is connected with the walls of the orbit, and whether it is affected by movements of the eyeball; and, in the cases of soft or fluid swellings, whether they are affected by respiration, or if pulsation can be felt on making pressure. When there is any suspicion of a malignant growth, the hard palate, nostrils, and posterior nares should be examined. Fluctuation can often be made out more easily if the globe be pressed back into the orbit; if, however, a layer of orbital fat lies over the tumour, a sensation may be given to the finger that is absolutely indistinguishable from the fluctuation of fluid.

Congenital tumours of the orbit are of peculiar interest and importance, because of the difficulty that occasionally arises in ascertaining whether they are connected or not with the membranes of the brain. They may be classified into three groups: (1) Cysts, (2) nævi, (3) meningoceles and encephaloceles.

The neighbourhood of the orbit is a favourite seat of the congenital subcutaneous or dermoid cysts. Most commonly they are situated near the outer angle, just above the supraorbital ridge. In this situation they are usually entirely external to the cavity of the orbit, and their removal usually presents little or no difficulty. Occasionally, however, when nearer the orbit, their superficial appearance proves on dissection to be illusory, and such cysts have sometimes been traced back far into the cavity; and occasionally after their removal an aperture in the roof has been found, through which the pulsations of the brain could be seen or felt.* As a rule, however, the tumour can be distinctly isolated, and is easily removed.

The contents of dermoid cysts are very variable, a circumstance which gave rise to a rather extensive nomenclature among the older authors. Most commonly they contain a substance resembling in appearance a bread poultice, which consists of epithelial cells and sebaceous secretion. This substance may have become converted into a fluid, or may, on the contrary, have become inspissated, or even calcified. More rarely fully developed dermoid structures, such as hairs, nails, and in some cases teeth, have been found.

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* *See* a case recorded by Mr. Holmes in his work on the "Surgical Diseases of Childhood."

The removal of such tumours should always be undertaken when they are evidently superficial, and in most cases in which the diagnosis from meningocele is quite clear. The possibility of the swelling being connected with the meninges should especially be borne in mind when the swelling is situated at the inner side of the orbit, as this is one of the common situations for a meningocele. Unless, therefore, such a swelling can be thoroughly isolated, it is best not to interfere.

Meningoceles have been known, however, to occur at the outer angle, and in one instance the protrusion into the orbit took place through the sphenoidal fissure. Probably the largest meningocele on record, as occurring in this part of the skull, is one shown by Dr. Riley at the Pathological Society.* The tumour, which measured twelve inches in circumference, protruded between the two halves of the frontal bone in a fœtus, and completely hid the right eye. It was punctured to facilitate delivery, and a quart of fluid was withdrawn from it.

The diagnosis between meningocele and subcutaneous cyst rests on the fact that the former is affected by respiration, and is sometimes partially or entirely reducible. If the communication with the cranial cavity be free these symptoms are sufficiently marked, but if, on the other hand, the orifice through which the hernia protrudes be small, the diagnosis may be difficult or impossible. In cases of this nature it

* Pathological Society's Transactions, vol. xvi. p. 8.

would be justifiable to make a puncture with an exceedingly minute trocar and to examine the fluid. In the cases of more solid encephaloceles a difficulty arises in distinguishing them from nævi, a difficulty which is sometimes even greater than in the former cases, as both tumours may be partly reducible on pressure, and both may pulsate, although the pulsating form of angioma is exceedingly rare as a congenital tumour. There is nearly always present, however, in nævi a discoloration of the skin or conjunctiva, either constantly present, or becoming apparent when the child cries. But it has happened to most experienced surgeons to be mistaken in such cases. Thus a case is recorded* in which M. Guersant passed setons through what was believed to be a subcutaneous erectile tumour at the inner angle of the orbit, with the result that the child died in a few days. At the post-mortem an encephalocele was found protruding through the fronto-ethmoidal suture. Two cases recorded by Mr. Holmes† show the difficulty of forming a diagnosis even after the exposure of the cyst. In both instances an operation was undertaken for the removal of what was believed to be a subcutaneous simple congenital cyst. In one the tumour, on being exposed, so exactly resembled a meningocele that the propriety of abandoning the operation was discussed. It was, however, completed, and the original diagnosis proved to have been correct. In the other case some difficulty was experienced in separating the supposed cyst from its deeper attachments, and it was accidentally punctured; the escape of a small quantity of brain matter at once revealed the true nature of the case, and the operation was of course abandoned: fortunately no ill effects followed.

Nævi are found occasionally within the orbit, having either originated within its cavity, or, more commonly, having encroached upon it from adjacent parts. In many cases the tumour is not observed till the early years of childhood; but in all it is probably present (at any rate, to some extent) at birth. The venous variety is the most common, but cases of arterial nævi, or of aneurism by anastamosis, have also been recorded, although, as far as I am aware, the diagnosis in the latter instance has never been confirmed by dissection.

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* *Presse Méd de Bruxelles*, 1851.

† *Loc. cit.*, p. 66.

When the tumour encroaches on the orbit from the surrounding integuments, the diagnosis is, of course, obvious; but this is far from being the case when it lies entirely within the cavity. The eyeball is then displaced by a soft tumour, which disappears or is considerably reduced by pressure; when the child cries, there is a marked increase in its size, and often a bluish discoloration of the skin or conjunctiva. In some instances the difference in the size of the tumour, caused by venous distension, is so great that nothing abnormal may be visible under ordinary conditions; yet when the child cries, the eye may protrude considerably.

Closely allied to venous nævi are cavernous or erectile tumours. Some of these are doubtless nævi which have undergone an incomplete fibroid degeneration; others would appear to have commenced in adult life. They are rare in any situation, but seem to occur with greater frequency in the orbit than elsewhere. Their growth is slow and painless, and they have a tendency to mould themselves to the structures in the orbit. If the tumour approach the surface, it can be felt to give a firm elastic resistance. In a few instances variations in the size of the swelling have been noticed, and this symptom would give rise to a strong suspicion as to its nature; but usually there is nothing by which it can be distinguished, before removal, from any other slowly-growing, non-inflammatory tumour. Some months ago the writer removed at St. George's Hospital a tumour of this nature from a girl aged 24. On section it was of a dark plum colour, of a very firm consistence, and was traversed in all directions by tendinous bands; between the latter were an innumerable number of round and oval spaces, of very variable size. Mr. Compton, who was then microscopical pathologist to the hospital, was good enough to examine the tumour, and reported as follows: "The bulk of the tumour consists of fibrous tissue; in this were numerous cavities, many of which are filled with blood corpuscles, and are evidently sections of blood-vessels. The latter appears to tunnel through the substance of the tumour without possessing any distinct walls other than an endothelium. In some situations there is a great abundance of nuclei, evidently undergoing development into fibrous tissue."

The treatment of nævi which extend deeply into the orbit is not free from risk. It is not safe to inject blood-coagulating fluids into them, as their circulation is entirely beyond the control of the surgeon, and emboli may easily be carried from them into the general blood current. If they are sufficiently accessible setons of thick silk may be passed through them in order to excite suppuration, and to hasten the degeneration of the tumour. Excision of a nævoid growth, unless it has undergone some amount of degeneration, is of necessity accompanied by a considerable loss of blood; and if, owing to the extent of the growth, it were found impossible to remove the whole of it, or to ligature the main vessels supplying it, the hæmorrhage might be difficult to check without using an amount of pressure which would endanger the safety of the eye. When therefore these tumours extend into the orbit beyond the reach of the finger, it is well to leave them alone in children, unless they are increasing in size. When they have been long stationary, and are to a great extent solid, their removal may be undertaken with more prospect of success; but even in such a case it must be borne in mind that the growth not unfrequently envelops the optic nerve in such a manner as may necessitate the abandonment of the operation if vision is to be preserved.

It should be remembered that nævi have a tendency to undergo degenerative and atrophic processes, and the surgeon should therefore be in no hurry to interfere actively, unless the tumour is actively growing. Occasionally a kind of cystic degeneration takes place, and in this way some of the blood cysts occasionally met with in the orbit may probably be explained.

Cystic tumours.—Of non-congenital tumours those of cystic formation are the most common; but many of these, although pathologically to be classed as cystic, are yet clinically indistinguishable from non-cystic tumours, since their contents are solid. Nor is the diagnosis of cysts with fluid contents always an easy matter; indeed, it can seldom be made with certainty without an exploratory puncture. Their growth is usually very slow and painless, and the symptoms of pressure on the optic nerve and other structures are less frequently present than in solid tumours.

The contents of a cystic tumour may consist of blood, of a thin serous fluid, of a more viscid fluid, like synovia, or of the limpid non-albuminous fluid of a hydatid. The dermoid cyst, which is probably always congenital, has been already sufficiently described.

Cysts with serous contents are the most common, with the exception perhaps of the hydatid. Unless they have been inflamed or previously tapped, the fluid is of a pale straw colour. They are usually, but not always, unilocular. They may originate in the eyelids or lacrymal gland, and extend thence into the orbit, or they may commence in the cellular tissue. In some the existence of solid matter in parts of the cyst wall would seem to indicate that it had been formed by cystic degeneration of a solid tumour.

These serous cysts appear to have a tendency to increase indefinitely, and sometimes attain enormous dimensions, causing atrophy of the optic nerve by pressure, and even distension of the orbital cavity. They have been known to extend into the cranial cavity through an aperture in the roof of the orbit, the sphenoidal fissure, or the enlarged optic foramen. Such cases are of course exceedingly rare, but their possibility must be borne in mind in considering the advisability of operative interference.

In treating cystic tumours of the orbit, an exploratory puncture should always be made in the first instance; this not only enables the surgeon to form an idea of its nature from an examination of its contents, but also gives an indication of its size. Occasionally puncture itself effects a cure, but more commonly the cyst refills, and the information that has been obtained will be useful in undertaking its removal, if it be thought advisable to attempt it.

Cystic tumours containing blood are occasionally met with, and have been described under the various names of "hæmatoma of the orbit," "sanguineous cyst," "hæmatocele," etc. Some of these are probably merely cases of hæmorrhage into the cellular tissue which has become encysted; but the majority would seem to have been serous cysts which have been punctured, and into which hæmorrhage has taken place in consequence; at any rate, there is a history of previous puncture in the large majority of such cases. Sometimes these blood cysts are associated with cavernous angiomata.*

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* *See* a case recorded by Mr. E. Holmes, *Chicago Medical Journal*, 1871.

In the beginning of the year 1884 I saw at the Royal London Ophthalmic Hospital an instance of one of these blood cysts; it occurred in a woman, aged 23, who, I believe, was a patient of Mr. Waren Tay. The cyst formed two globular swellings at the inner extremities of the upper and lower eyelids respectively; the two evidently communicated freely, for either could be made to disappear by pressure, when the other immediately became more prominent. The patient stated that she had come to the hospital five years previously for a similar swelling, which had appeared soon after a blow upon the eye, that it had been punctured, and a week later incised, that nothing escaped from it but blood, and that the swelling entirely disappeared. Nine days before her second visit she received a blow on the eye; on the third day she noticed the swelling. An incision was made into the cyst, and about an ounce of fluid blood escaped, and the swelling entirely disappeared. It seems difficult in this case to account for the exact similarity of the swellings on the two occasions, except by assuming that there was a pre-existing cyst, into which the hæmorrhage took place. As to the nature of the contents on the first occasion, it was merely stated in the notes that it was a bloody fluid, and that the blood corpuscles showed a great tendency to form rouleaux.

Spontaneous extravasations of blood large enough to cause any protrusion of the globe could hardly occur independently of extensive degeneration of the vessels, or deterioration in the quality of the blood. Extravasations of large size are, however, not uncommon as the result of injury, and will be considered under that heading.

Hydatid cysts occur with greater frequency in the orbit than in any other part of the body except the liver. Their growth is slow, and they seem seldom to have attained a large size. If they reach the surface, fluctuation may be detected; but there is no mode of distinguishing them with certainty from other cysts until an exploratory puncture has been made and the fluid examined. More often the cyst is deeply placed, and then it may be impossible to distinguish it from a solid growth. Judging from recorded cases, signs of inflammation of the optic nerve appear to occur more frequently with hydatid tumour than with any other form of equally slow growth.

If the cyst be punctured, the escape of a colourless, non-albuminous fluid, which may contain some of the characteristic hooklets, will establish the diagnosis. Sometimes the withdrawal of the fluid is followed by the death of the echino-coccus and the shrivelling of the cyst, but this is exceptional, and its removal is generally necessary. There is usually no difficulty in removing the sac entire; but if, from its large size, or from the presence of adhesions, this be found to be impossible, it should be laid freely open: it will then sometimes come away of itself, or the cavity may fill up by granulation.

Fatty tumours are occasionally met with in the orbit, but they seldom attain a large size. They appear to be always situated outside the cone of muscle, and to appear early in the palpebral fissure, usually at the outer canthus. As their extension is chiefly in a forward direction, and as they are of soft consistence, they have little tendency to displace the globe.

Tumours described as **fibrous** and **fibroid** have been removed from the orbit; some of these were doubtless true fibromata, *i.e.* formed of fully developed fibrous tissue, but the majority were probably examples of recurrent fibroid, or fibro-sarcoma. Most are described as traversed by band of fibrous tissue, and presenting numerous elongated, nucleated, spindle-shaped cells, while in the substance of the tumour are usually several cysts. In their clinical characters they differ from the more malignant sarcomata in their slow growth, and in the fact that they less frequently recur after removal, and when they do it is usually after a long interval; they show, moreover, no tendency to invade the eyeball, although of course they may destroy it by pressure.

Exostoses of the orbit occur most frequently on the inner wall or roof, but may be situated at any part. They are usually of the ivory variety, having a hard nodular surface, perforated by numerous minute foramina. Their growth is extremely slow, and some remain of small size, and are hard and compact throughout; others attain in the course of years enormous dimensions, and in these there are usually irregular intercommunicating cavities, which usually open on the surface by several large irregular orifices. An example of this form of tumour is to be seen in the Museum of the Royal College of Surgeons (No. 3236 A). An exostosis, larger than a man's fist, projects from each orbit, and extends into the zygomatic fossæ and pterygoid fossæ; both orbits are filled with the growth, and the eyes had been forced out. The specimen was taken from a man, aged sixty, in whom the tumours had been growing eighteen years.

It must be borne in mind that not unfrequently these tumours, although appearing to be attached to the orbital walls, in reality spring from the interior of the adjacent air sinuses.

The smaller exostoses are usually sessile, and as their substance is extremely hard their removal is a matter of great difficulty. The larger tumours not unfrequently have comparatively slender pedicles, although from their large size and rounded shape it is not as a rule possible to ascertain before operating whether this is the case or not. When thus pedunculated, the tumour may sometimes be broken off from its attachment.

When the tumour is within reach of the finger, the diagnosis is comparatively easy, a subperiosteal node and distension of the frontal sinus being the only affections with which it could be confounded; the latter would generally be distinguished by there being some elastic yielding of the bone on making firm pressure. Occasionally, however, an almost bony hardness is given by fascia being very tightly stretched over a soft swelling. The writer has more than once seen a small dermoid tumour that could not with certainty be distinguished from an exostosis.

When the history justifies a suspicion of the tumour being syphilitic, the effect of a course of iodide of potassium should be tried, tumours that have been diagnosed as exostoses occasionally having been known to disappear under its influence.

When the tumour is situated far back, a certain diagnosis is impossible, as the symptoms are common to any slowly growing tumour.

The removal of exostoses is often difficult and frequently impossible, yet if the tumour is certainly growing the attempt should be made.

It is sometimes impossible to cut through the pedicle owing to its hardness. The vitality of these tumours seems to be very low, and several instances have been recorded in which a violent blow, or an abandoned operation, has been followed by its death and detachment. The small size of the pedicle and the leverage afforded by the large size of the tumour sometimes enable the latter to be detached without much apparent force being required. Such manœuvres are, however, not free from danger, especially when the attachment is to the roof of the orbit, as a portion of the latter may be easily wrenched off and a fatal meningitis set up. It would generally, therefore, be more prudent to first weaken the pedicle by boring it with a dental drill. It may be necessary to attempt the removal of tumours in this situation on account of the pressure they are causing on the brain. Thus recently Mr. Victor Horseley successfully removed an ivory exostosis which had perforated the roof of the orbit, extended some distance into the brain, and had caused epilepsy.

A remarkable instance of spontaneous detachment of an exostosis was a case read before the Ophthalmological Society by Dr. Lediard,* who exhibited the tumour. The latter was nearly spherical in shape, and about 4½ inches in diameter; it had been noticed at birth, when it was the size of a pea, and was situated on the upper margin of the orbit. It steadily increased in size, and at the age of seven caused destruction of the eye. At twenty, its growth ceased, but the skin over it became ulcerated. A few years later, without any warning or known cause, the tumour fell and struck the patient's foot. In this case the pedicle was of considerable thickness, and its fracture was no doubt due to degenerative changes which had commenced as soon as the tumour had ceased to grow.†

Malignant tumours may commence in the cellular tissue, in the bony walls, or in the globe, or they may invade the orbit from neighbouring cavities. Sarcoma is much more frequent than carcinoma, but the distinction is clinically unimportant, since both tend rapidly to invade the adjacent cavities, and to cause death by secondary deposits, or by direct extension to the brain. Their growth is usually rather rapid from the first, but it becomes much more so, when, by perforation of the walls of the orbit, or by protrusion from its anterior orifice, resistance is diminished. The lymphatic gland which first becomes affected is the one over the parotid gland.

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* Trans. Oph. Soc., vol. iii. p. 23.

† For fuller information, *see* Andrews, "Osteomata of the Orbit," *New York Medical Record*, Sept. 3, 1887.

The nature of the tumour varies much, some being soft, and so vascular that pulsation can be felt in them; others of cartilaginous firmness. They occur, too, in patients of all ages, although childhood and advanced middle life are most liable to be attacked.

Pulsating malignant tumours of the orbit are generally associated with similar growths elsewhere, especially in the flat bones, as the sternum, parietal bone, and scapula; this is, however, not always the case. Sometimes the pulsation is distinctly visible, in other cases it can only be made out by firm pressure; it is not of the distensile character peculiar to an aneurism, and the diagnosis between these affections never presents any difficulty.

Glioma always commences in the retina, involving the orbit by extension; it has already been considered with affections of the retina.

Many instances of so-called *melanotic sarcoma* have been recorded. In most of these the pigmentation which has given rise to the name, and which sometimes renders the tumour almost jet-black, would seem to be an accident depending on the situation of the growth. As regards those which have commenced in the choroid, and thence spread to the orbit, this is certainly the case, and it is probably also true of other tumours which have commenced external to the eye. At any rate, these tumours do not appear to possess that extreme malignancy which is characteristic of melanotic sarcoma when it occurs in other parts of the system.

It is of the utmost importance to diagnose a malignant tumour of the orbit at the earliest possible moment. Rapidly growing non-inflammatory swellings within the orbit should at once arouse a strong suspicion of malignancy, and no time should be lost in operating. It must, however, be as far as possible ascertained that there is a reasonable probability of the whole growth being accessible, as partial operations are worse than useless; hence the palate, pharynx, posterior nares, and anterior surface of the superior maxilla should be examined for evidence of extension of the tumour. Having decided that the removal of the growth is probably feasible, the question arises, when vision is still unimpaired, whether the eye is to be sacrificed. Sometimes this must be done in order to get the tumour away, and there can be no question that in all cases of malignant growth by far the safest plan is to remove the whole of the contents of the orbital cavity, and freely to cauterise the walls if they present any suspicious appearance; but at the first operation there is often sufficient doubt as to the exact nature of the tumour to make us hesitate to recommend so radical a proceeding; if, however, after one operation, a recurrence of the growth occurs, all hesitation must be thrown aside. The following case illustrates some of these points:

Leah C., 13, was admitted into St. George's Hospital, under Mr. Brudenell Carter's care, on March 5th, 1874. The left eye was displaced downwards and outwards by a tumour which distended the upper lid. The swelling was of recent origin, and said to be increasing rapidly. On the following day there was a perceptible increase in its size, and vision for the first time was slightly impaired. An incision was made through the upper lid, and the growth exposed; it was of reddish-grey colour, and of moderately firm consistence, but it broke down on being seized with the forceps. There were no adhesions, and it was removed without difficulty. The wound healed by first intention. On May 2nd the patient was re-admitted with recurrence of the tumour. Mr. Carter wished to remove the whole of the orbital contents, but after a consultation it was decided to remove the tumour only. On making an incision, the growth was found to have infiltrated all the tissues, and to have extended far back towards the apex of the orbit. On the following day the eyelids, and the whole of the contents of the orbit were removed, the hæmorrhage was arrested by the actual cautery, and the cavity stuffed with chloride of zinc paste. The bones of the orbit were exfoliated, and the patient made a good recovery.*

Injuries of the orbit, which may be divided into contusions and penetrating wounds, may endanger the sight by direct injury to the globe or to the optic nerve, or may endanger life by implication of the brain or its meninges. In a third class of injuries the carotid artery is wounded in the cavernous sinus. (*See* page 534.)

Contusions easily produce considerable ecchymosis of the lids, owing to the quantity of loose cellular tissue in them. There is often at the same time effusion of blood beneath the ocular conjunctiva, which forms a uniform red layer surface, which stops short just external to the corneal margin, from which it is separated by a well-defined white line. Ecchymosis of the eyelids rarely occurs spontaneously, except in abnormal states of the blood, as in scurvy, but that beneath the conjunctiva frequently occurs without any obvious cause; sometimes it is produced by straining, as in coughing, or during parturition, occasionally it occurs during the night, and has then sometimes led to a suspicion, which the subsequent history has confirmed, of the patient having had an epileptic seizure.

It should be borne in mind that subconjunctival hæmorrhage is one of the symptoms of fracture of the anterior fossa. When due to this, the amount of blood increases as it is traced backwards, whereas the local hæmorrhage generally diminishes in proportion to the distance from the cornea. When there is a very great swelling of the lids, a very extensive fracture of the bone may readily be overlooked.

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* Clin. Soc. Trans., vii.

When, as the result of a severe contusion, hæmorrhage takes place into the cellular tissue of the orbit, a suspicion of a fracture crossing the optic foramen and severing the ophthalmic artery should always be aroused. In such cases the optic nerve is likely to be torn across, or so compressed within the foramen that its function is destroyed. These large extravasations cause considerable protrusion of the globe, and even if the nerve is not immediately injured by the accident, it may be destroyed by the sudden stretching to which it is subjected. They do not, as a rule, pulsate; the pulsating swellings which sometimes follow an injury are due to a different lesion. (*See* page 534.)

Under the influence of rest, pressure, or the application of ice, the hæmorrhage generally ceases, and the blood is slowly absorbed. In some cases it has been thought advisable to cut down and turn out the clots. Occasionally the blood has been known to form by its coagulation a solid tumour, which has undergone no further change in the course of several years.

Severe blows in the region of the orbit, which do not cause any orbital ecchymosis, yet occasionally give rise to ocular symptoms, such as flashes of light, and more rarely total but temporary blindness of one eye. These symptoms may probably be caused in several ways, as by direct concussion of globe, concussion of the optic nerve in its passage through the foramen, and disturbance of the cerebral centres. Sometimes the blindness has been permanent; in such cases there are at first no ophthalmoscopic signs, but after a few weeks the optic disc always becomes atrophic.

The absence of all changes in the fundus shows that the lesion is situated behind the point at which the vessels leave the nerve (about 15 mm. behind the globe), probably at the optic foramen.

Emphysema of the cellular tissue of the orbit and eyelids may follow a blow which ruptures some of the ethmoid cells, or it occasionally occurs without any previous injury during violent blowing of the nose. The lids become distended by a puffy swelling which gives the well-known crackling sensation to the fingers, and the globe may be prominent. The prognosis is absolutely favourable, although the symptoms are sufficiently alarming to the patient.

Penetrating wounds are of importance from the risk of injury to the nerves and vessels within the orbit, and from the ease with which they pass into the cranial cavity.

It is always difficult to gauge the extent of the injury; the patient's statements as to the nature of the implement, and its condition before and after the infliction of the wound, and the direction and force of the thrust, are vague or misleading; and the orbital fat may at once close over and conceal foreign bodies of considerable size. In the museum of St. George's hospital is preserved an iron hat-peg, three inches and three-tenths in length, and weighing twenty-five scruples. The patient from whom it was taken had fallen whilst intoxicated against the peg, which had entered his orbit and broken off; he did not seek advice until three days after the accident, and was then for five days under medical care before the presence of the foreign body was discovered. Smaller bodies have been retained for many years. Thus Pagenstecher records a case * in which a piece of steel knitting needle remained in the orbit, partly implanted in the inner wall, for seventeen years, keeping up frequent attacks of inflammation which led to loss of vision, and eventually to sympathetic irritation of the other eye. Enucleation was performed, but the foreign body was not discovered until the woman was examined to ascertain the cause of healing being delayed. As a rule, however, the retention of a foreign body leads to the establishment of a fistula.

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* *Oph. Rev.*, i. 342; old series.

When large blood-vessels have been wounded, the eye is rendered prominent by the extravasation, and the pressure and traction upon the optic nerve may lead to its atrophy. In some cases a pulsating swelling has appeared in the orbit some months later. It is possible that in some of these cases an arterio-venous communication has been established within the orbit, and an aneurismal varix, or varicose aneurism resulted; but this has never been demonstrated by dissection, and the symptom usually indicates that the wound has penetrated the carotid artery in the cavernous sinus.

When a penetrating wound results in immediate and total blindness, injury to the optic nerve is indicated. When the lesion is behind the point at which the central vessels leave the nerve (about 15 mm. behind the globe), there are no immediate changes visible with the ophthalmoscope, but secondary atrophy always supervenes in a few weeks. When the injury is in front of this point, optic neuritis is always developed very rapidly with much swelling of the disc and retinal hæmorrhages.

Injury to the optic nerve frequently results from wounds with blunt instruments, while sharper weapons more often sever smaller nerves, thus leading to paralysis of certain of the external muscles.

Penetrating wounds may easily extend into neighbouring cavities; thus, foreign bodies which have entered the orbit have sometimes been expelled years afterwards through the nose.* In the same way the frontal, ethmoidal, and maxillary sinuses have frequently been penetrated. Much more important, however, are the wounds that penetrate the cranial cavity. This may readily occur either through the roof or at the apex of the orbit. As regards the former, it should be remembered that the frontal sinus does not exist in children, and is of very variable size in the adult; and with any injury of the upper part of the orbit, the possibility of the cranial cavity being involved should always be borne in mind. The further consideration of such cases belongs rather to the domain of general than of special surgery.

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* Zander and Geissler, Verletz. des Auges.

When the apex of the orbit is penetrated, the carotid artery in the sinus may easily be wounded. If a fatal result does not ensue from hæmorrhage, aneurismal varix extending to the orbital veins is likely to follow. (*See* page 534.)

The case of shot wounds differs from those inflicted by a thrust, in the impossibility as a rule of ascertaining the direction and extent of the track of the shot, and in forming an opinion as to whether any foreign matter has been retained. Mr. Carter has given me the particulars of a case in which a bullet wound of the right temple appears to have passed across the optic, olfactory, third and fourth nerves of both sides, before emerging at the left temple.

Luxation of the eyeball is the term applied to such a protrusion as carries the equator of the globe in front of the eyelids, so that they grip it and prevent it returning to its orbit.

If the eyeball is already unnaturally prominent, luxation may take place when the lids are held apart, but it may be produced in the normal condition by a blunt body being introduced into the orbit.

Evulsion is the term applied to the forcible tearing away of a luxated eyeball from its attachments.

Immediate reduction of a luxated eyeball should always be effected, as in a few instances vision has been restored, although it was completely absent until reduction was effected. Evulsion has occasionally been followed by death from meningitis.

Pulsating exophthalmos.—Under this title are included a number of cases which differ from each other in many respects, but have in common, as their most prominent symptoms, a pulsating swelling in the orbit and prominence of the eyeball.

In the majority of cases the onset has been sudden and directly traceable to an injury to the head. The latter has frequently been accompanied by symptoms of a fracture of the base of the skull; thus out of sixty-five traumatic cases there was almost certainly fracture of the case in twenty-one, and possibly in fifteen others. In other cases injury has consisted in a wound of the affected or opposite orbit, and in one case of a pistol-shot in the mouth.* Usually the first symptom noticed has been an intermittent buzzing or whizzing sound in the head synchronous with the heart's action. This has been followed, after an interval varying from a few weeks to many months, by gradually increasing prominence of the eye, and by the appearance of a soft swelling, usually at the upper and inner angle, possessing an aneurismal thrill, pulsation, and bruit. Sometimes the swelling extends on to the forehead and face, in the course of the supra-orbital and angular veins.

When the onset has been spontaneous, it has usually been indicated by a loud snap in the head, audible to the patient.

The earlier cases were diagnosed as orbital aneurism. Later dissections have, however, shown that in the majority of cases the primary lesion is intracranial, and consists in the establishment of a communication between the carotid artery and the cavernous sinus. From this an aneurismal varix results; the stream of blood flows from the artery into the sinus and orbital veins, which it gradually distends, and it is these latter which form the soft, bossy tumour already described.

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* Schlæfke, *Archiv f. Ophthal.*, iv. p. 117; 1879.

The lesion has been caused in a variety of ways: by a fracture of the base crossing the sinus; by a thrust-wound in the orbit of the same side; and by a wound of the opposite orbit passing through the body of sphenoid, and wounding the artery as it lay in the sinus; and it has occurred spontaneously owing to the giving way of an atheromatous patch, or the rupture of an aneurism.

Although this is the pathology of the majority of the cases of pulsating exophthalmos, a few have occurred of a different nature. It is possible that in some of the cases in which the symptoms followed a wound of the orbit, they were due to an arterio-venous communication within that cavity. This has never, however, been proved by dissection. An aneurism of the ophthalmic artery might produce similar symptoms; but although this lesion has been found in the post-mortem room,* its existence has not been proved in any case in which the symptoms were noted during life.

A pulsating malignant tumour has been the undoubted cause of the symptoms in at least one case, and in this there were similar tumours in other parts.

The course of the cases of aneurismal varix is extremely chronic, and in some instances spontaneous cure eventually results. In a case which was under the writer's care,† the pulsating swelling dated from a fracture of the base at the age of ten; the patient was forty when last seen, and the swelling had not undergone any increase for many years; and although occasionally painful, it did not prevent him from following hard manual labour.

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* Nunneley, Med.-Chir. Trans., xlii.

† Frost, Trans. Oph. Soc., iii. p. 18.

Treatment of various kinds has been adopted. Ligature of the common carotid has been practised in a large number of the cases, and has led to a complete cure in about half of those published, and to considerable improvement in some others. But unless the swelling were increasing in size, or there appeared to be a risk of its rupture, one would hesitate to recommend so formidable an operation. The contents of the swelling being in free communication with the general circulation, the injection of coagulating fluids is fraught with grave peril, although it has occasionally been successful. Rest, low diet, and the administration of digitalis, pressure, and the application of ice to the swelling, are all measures, that have in some cases proved successful, and they should be tried before ligation of the carotid is resorted to.

When the growth is malignant the co-existence of other tumours usually precludes all operative interference.*

Affections of the neighbouring cavities may extend to the orbit, or may sometimes appear to originate in that cavity. The production of a pulsating swelling in the orbit from an intracranial lesion has already been referred to; the eye may also be rendered prominent by the extension of any intracranial growth into the cavity of the orbit, or by obstruction to the circulation through the cavernous sinus. The latter, however, may occur, either from phlebitis or the pressure of a tumour, without the production of any orbital symptoms, if the anastomosis between the orbital and facial veins is sufficient to carry on the circulation. Usually, however, there is at the same time loss of power of all the external muscles of the eyeball, and anæsthesia of the cornea, from implication of the nerves in the sinus; if associated with this there is proptosis of the eye on the same side, afterwards appearing on the other also, it indicates that the phlebitis has extended to the opposite cavernous through the circular sinus. Cases of phlebitis of the cavernous sinus may occur as the result of inflammation extending from the orbit, or be due to pyæmia; they usually terminate fatally from meningitis.

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* For further information on this subject the reader is referred to the papers already quoted, and to Sattler, Graefe-Saemisch's "Handbuch der gesammten Augenheilkunde."

Distension of the frontal sinus gives rise to a smooth rounded swelling at the upper and inner angle of the orbit, which may be mistaken for an orbital tumour. These cases appear to be caused by a blocking of the outlet of the sphenoidal and frontal sinuses into the middle meatus of the nose, which has usually been produced by an injury, but has occasionally followed one of the acute exanthemata of childhood. When the swelling is first visible it forms a smooth rounded prominence rising gradually from the surrounding bone, and therefore in some respects resembles an exostosis; from this, however, it can be distinguished by the fact that its wall yields somewhat to firm pressure. As the distension increases the eyeball is displaced outwards; at the same time the bony wall undergoes absorption, and the swelling becomes soft and fluctuating. It can, however, generally be distinguished from a soft tumour by the raised condition of the bone at its base. Not unfrequently suppuration takes place, and the skin gives way; the opening then contracts into a sinus, which may remain open an indefinite time.

As the condition is one which cannot disappear spontaneously, an early incision should be made, and the contents, which are generally of a glairy consistence, should be evacuated. Sometimes this suffices to effect a cure, usually however it is necessary to provide a permanent outlet for the fluid; this can best be done by passing a stout probe from the opening into the nose, and carrying a drainage tube through its track. As the discharge diminishes, the tube can gradually be drawn down, and the external wound be allowed to close.

In addition to the cases of proptosis already described, which were entirely dependent upon a local lesion, and usually confined at first to one eye, there are others which depend upon constitutional conditions and which usually affect both eyes.

In this connection must be mentioned a class of cases, of which at present only a few examples have been recorded, and whose pathology is not understood. The most noticeable symptom is the dropping from the nose of a clear fluid; there is usually at the same time some optic neuritis. The cessation of the flow of fluid is usually followed by headache, or even by coma, symptoms which subside when it becomes re-established. The most probable explanation of the symptoms is that the fluid is derived from an excess in the subarachnoid cavity, and that it enters the nose through an opening in the cribriform plate of the ethmoid. The analysis of the fluid in some of the cases, however, has given results which are hardly consistent with this view.*

Exophthalmic goitre (*syn.* Basedow's or Graves' disease) is an affection in which the proptosis is usually accompanied by enlargement of the thyroid gland, palpitation and hypertrophy of the heart, and other general symptoms. The relative prominence of these different symptoms varies much in different cases. We shall only concern ourselves here with the condition of the eyes. They are prominent, and owing to the extent to which the lids are separated, their prominence appears even greater than it really is. This widening of the palpebral fissure is chiefly due to retraction of the upper lid (Stellwag's symptom), and together with the dilatation of the pupils which is often present seems to point to some irritation of the sympathetic. The movements are unimpaired, but the association of the upward and downward movement of the eyelids with that of the globes is often lost (Graefe's symptom). There is generally also an absence or infrequency of the involuntary blinking movements that take place frequently in the natural condition. Vision is unaffected, and as a rule there are no changes to be seen with the ophthalmoscope, although occasionally pulsation is to be seen in the retinal arteries. The disease is much more common in women than in men, and generally appears between puberty and middle life. The prominence of the eyes has sometimes been so great that sloughing of the cornea has occurred. As a rule, however, it is the general condition which is the most alarming, the patient being much distressed by the palpitation, and dyspnœa after any exertion, and being frequently very excitable and irritable. Although some cases run an acute course and terminate fatally, as a rule they are extremely chronic, and many recover completely.

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* See *Oph. Rev.*, pp. 2, 242; 1883.

The cause of the proptosis is not fully known; in some cases it has entirely disappeared after death, and in such it was probably due to obstruction to the venous circulation; in others there has been found an increase in the amount of cellular adipose tissue in the orbit.

Nothing is known with certainty as to the essential cause of the disease. In some cases changes have been found in the cervical sympathetic, but these have not been constant either in their existence, or in their nature when present, and may therefore have been either accidental or secondary. The wide area over which the symptoms are distributed would lead one to suspect a central lesion as the cause, but none such has hitherto been discovered.

Treatment must be directed towards the general condition, and therefore belongs rather to the domain of the physician. A large variety of remedies has been tried, such as iron, digitalis, belladonna, veratrum and many others, without, however, any one of them having been found to possess any marked superiority; indeed, the symptoms vary so much that the choice of the line of treatment to be adopted will necessarily vary in different cases, and will depend upon conditions which are too wide for discussion here. The only local treatment which has met with any large measure of success is the application of the constant current to the cervical sympathetic.

Occasionally cases occur in which proptosis is the only symptom. This sometimes comes on with great rapidity, and it may affect one or both eyes. It occurs more frequently in women than in men, and most have come on about the climacteric period. It is, however, occasionally met with in young girls. The pathology of these cases is quite obscure; in some cases it probably depends upon a loss of muscular tone in the recti, which does not affect the movements of the eye, since the relative strength of the muscles remains unaltered; in such the proptosis is reducible by pressure, in others there is probably an increase in the orbital contents. A case has been recorded* in which external prominence of both eyes always occurred during mastication.

The deformity produced by slight proptosis may sometimes be removed by uniting the lids at the outer extremity of the palpebral fissure.

Sinking of the globe (or enophthalmos, as it has been called) is occasionally met with; in some cases it is probably due to absorption of the orbital fat, in others to paralysis of the cervical sympathetic, when it is accompanied by narrowing of the palpebral fissure and contraction and immobility of the pupil. W. A. F.

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* *Klin. Monatsbl.*, May, 1888.

APPENDIX A.

SNELLEN'S DISTANCE TYPES.

D=24

L D

D=18

T E

D=12

Z T E

D=9

L Z T O

D=6

T R F P A

READING TYPES.

(AFTER SNELLEN.)

The figures indicate approximately the distance in metres at which each type subtends an angle of five minutes.)

No. 0·3.—*Semi-Minion.*

It happened one day about noon, going towards my boat, I was exceedingly surprised with the print of a man's naked foot on the shore, which was very plain to be seen in the sand. I stood like one thunderstruck, or as if I had seen an apparition; I listened, I looked round me, I could hear nothing, nor see anything; I went up to a rising ground, to look farther; I went up the shore and down the shore, but it was all one, I could see no other impression but that one; I went to it again to see if there were any more, and to observe if it might not be my fancy, but there was no room for that, for there was exactly the very print of a foot, toes, heel, and every part of a foot; how it came thither I knew not, nor could I in the least imagine. But, after innumerable fluttering thoughts, like a man perfectly confused and out of myself, I came home to my fortification, not feeling, as we say, the ground I went on, but terrified to the last degree, looking behind me at every two or three steps, mistaking every bush and tree, and fancying every stump at a distance to be a man; nor is it possible to describe how many various shapes affrighted

No. 0·6.—*Pearl.*

for never frightened hare fled to cover, or fox to earth, with more terror of mind than I to this retreat. I slept none that night; the farther I was from the occasion of my fright, the greater my apprehensions were; which is something contrary to the nature of such things, and especially to the usual practice of all creatures in fear: but I was so embarrassed with my own frightful ideas of the thing, that I formed nothing but dismal imaginations to myself, even though I was now a great way off it. Sometimes I fancied it must be the Devil, and reason joined in with me upon this supposition; for how should any other thing

No. 0·8.—*Minion.*

upon him in such a place, where there could be no manner of occasion for it, but to leave the print of his foot behind him, and that even for no purpose too, for he could not be sure I should see it; this was an amusement the other way; I considered that the Devil might have found out abundance of other ways to have terrified me than this of the single print of a foot; that as I lived

No. 1·0.—*Bourgeois.*

the first surge of the sea, upon a high wind, would have defaced entirely: all this seemed inconsistent with the thing itself, and with all the notions we usually entertain of the subtlety of the Devil. Abundance of such things as these assisted to argue me out of all apprehensions of its being the Devil: and I presently concluded then, that

No. 1·25.—*Pica.*

While these reflections were rolling upon my mind, I was very thankful in my thoughts that I was so happy as not to be thereabouts at that time, or that they did

No. 2.—*Great Primer.*

in the place, and perhaps have searched farther for me: then terrible thoughts

No. 2·3.—*Double Pica.*

their having found my boat, and that there

No. 3·0.—2-*line Great Primer.*

that if so, I should certainly have

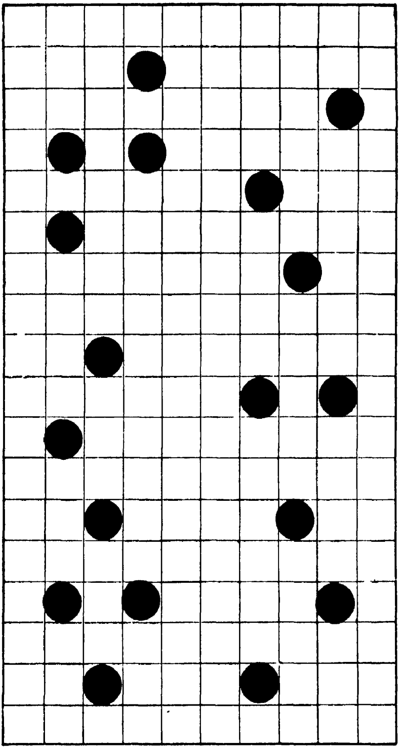
No. 4·5.—4-*line condensed.*

them come

APPENDIX B.

ARMY TEST DOTS.*

Each dot has a diameter of ⅕th in., and therefore at a distance of ten feet subtends the same angle as a bull's eye three feet in diameter at a distance of 600 yards.



A few of the dots should be exposed, the remainder being covered with a card.

Candidates for the Royal Artillery and Royal Engineers must be able to count the dots with each eye separately at 22½ feet; Line recruits at 10 feet; Militia recruits at 5 feet.*

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* The diagram has been copied by permission from Messrs. Pickard & Curry's card.

† "Rules regarding Defects of Vision," by Sir J. Fayrer. J. & A. Churchill, 1886.

APPENDIX C.

A METHOD OF MOUNTING AND PRESERVING ENUCLEATED EYES.

THE following directions are copied from an article by Mr. Priestley Smith (*Ophthal. Rev.*, ii. p. 69), a few modifications which the writer has found useful being introduced :—

Hardening.—Immediately after excision the eye is placed, unopened, in Müller's fluid (bichromate of potash, 25 parts, sulphate of soda, 10 parts, water, 1,000 parts). Light is carefully excluded, and it is kept in the fluid about three weeks.

Freezing and Cutting.—If the optic nerve has been cut long it is better to split this with a sharp knife down to the level of the sclerotic, in the plane of the intended section, which should be marked by a thread tied round the eye, as landmarks are often unrecognisable after freezing. The surface of the eye is then to be oiled, and it is enveloped in a piece of thin guttapercha tissue. The eye is frozen by immersion, for not less than half an hour, in a mixture of equal parts of ice and salt. The vessel should allow of free drainage, an ordinary flower-pot answers the purpose admirably. The guttapercha is then removed, and the eye can be easily divided with a table knife.

Preparation for Mounting.—Immediately after section, the eye is placed with the cut-surface upwards in a 5 per cent. solution of chloral hydrate, with a view of removing the stain of the Muller's fluid; the solution is changed until it no longer becomes discoloured. The specimen is then transferred successively to 10, 25, and 50 per cent. solutions of glycerine in water, remaining in each about two days; if, however, it is not convenient to proceed to the mounting, it may remain in the 50 per cent. glycerine an indefinite time.

Mounting.—A glass jar is required, the bottom of which must be perfectly transparent, and free from flaws.* This is partly filled with a melted jelly. This is made by mixing French gelatine, one part, glycerine and water, each six parts. The gelatine is soaked in the water till it is swollen, it is then melted in a water-bath, and the glycerine is added. A few drops of carbolic acid should be added. Jelly thus made will keep for an indefinite time, and is sufficiently clear for the purpose; if wished, however, it can be clarified with white of egg, and filtered. Some of the melted jelly having been poured into the glass jars, the specimen is carefully placed in it, concavity upwards. As soon as all the interstices have been well filled, it is carefully turned over with two cataract needles so that the cut surface rests against the glass bottom; in doing this care must be taken that an air bubble is not included. As the jelly solidifies, it is sometimes necessary to hold the eye down with a needle.

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* These are made by Messrs. Osler, of Oxford Street, London, and Birmingham. The smallest size will hold one-half of the bisected eye.

Finishing.—When the jelly is hard, a card may be gummed over the open end of the jar, care being taken, however, that it is nowhere in contact with the jelly. The card protects the specimen, makes a neat background for it, and is convenient for labelling.

The writer has kept eyes mounted in this way for several years without any deterioration taking place.

APPENDIX D.

FORMULÆ.

1.—**Causticum Zinci Chloridi.**

Chloride of zinc, 8 parts.
Flour, 3 „
Water, 8 „
To be made into a paste.

A powerful caustic. Used for destroying malignant growths.

2.—**Guttæ Acidi Borici.**

Acidi borici, gr. iv.
Aquæ, ℥i.

A mild astringent for conjunctivitis.

3.—**Guttæ Acidi Borici cum Cocainâ.**

Acidi borici, gr. iv.
Cocainæ hydrochloratis, gr. ii.
Aquæ, ℥i.

4.—**Guttæ Argenti Nitratis.**

Argenti nitratis, gr. ii.
Aquæ, ℥i.

A useful astringent in purulent conjunctivitis.

5.—**Guttæ Atropinæ Sulphatis (B. P.).**

6.—**Guttæ Atropinæ Sulphatis Mitiores.**

Atropinæ sulphatis, gr. ii.
Aquæ, ℥i.

7.—**Guttæ Cupri Sulphatis.**

Cupri sulphatis, gr. ii.
Aquæ, ℥i.

Used as an astringent in conjunctival affections.

8.—**Guttæ Duboisinæ.**

Duboisinæ sulphatis, gr. ii.
Aquæ, ℥i.

A mydriatic which may be substituted for atropine when the latter causes conjunctival irritation. It occasionally causes cerebral symptoms.

9.—**Guttæ Homatropinæ.**

Homatropinæ hydrobromatis, gr. vi.
Aquæ, ℥i.

Its effect is similar to that of atropine, but is more transient.

10.—**Guttæ Physostigminæ (*Syn.* Guttæ Eserinæ).**

Physostigminæ, gr. ii. ad gr. iv.
Aquæ, ℥i.

A myotic. Used in glaucoma, and some forms of corneal ulcer.

11.—Guttæ Quininæ.

Quininæ sulphatis, gr. iii.
Acidi sulphurici diluti, q.s.
Aquæ, ℥i.

12.—Guttæ Zinci Sulphatis.

Zinci sulphatis, gr. ii.
Aquæ, ℥i.

Used as an astringent in conjunctival affections.

13.—Lamellæ Cocainæ (B. P.).

Each contains $\frac{1}{200}$th of a grain of the hydrochlorate of cocaine, but they may be used of any strength from this to $\frac{1}{50}$th of a grain.

14.—Lapis Divinus.

Sulphate of copper.
Alum.
Nitrate of potash.

Equal parts, fused together and run into moulds to form sticks. Used as an application to granular lids.

15.—Liquor Acidi Borici.

Acidi borici, gr. viii.
Aquæ, ℥i.

Used as a mild astringent in conjunctival affections.

16.—Liquor Aluminis

Aluminis, gr. ii. ad iv.
Aquæ, ℥i.

As preceding, but slightly more astringent.

17.—Liquor Argenti Nitratis.

Argenti nitratis, gr. v. ad gr. xxx.
Aquæ, ℥i.

A powerful astringent, and a caustic in the stronger solutions. May be applied with a brush to the palpebral conjunctiva.

18.—Liquor Boro-glyceridæ.

Boro-glyceridæ (Barff's), ʒiss.
Aquæ, ℥i.

An antiseptic application which does not cause any conjunctival irritation.

19.—Liquor Hydrargyri Perchloridi (1 in 4000).

Hydrargyri Perchloridi, gr. ijss.
Aquæ destill., Oj.

20.—Liquor Sodæ Bicarbonatis.

Sodæ bicarbonatis, gr. x.
Aquæ, ℥i.

To be mixed with an equal part of warm water, and used for removing the crusts in blepharitis.

21.—Mistura Hydrargyri cum Ferro.

Liquoris hydrargyri perchloridi, ʒi.
Tincturæ ferri perchloridi, ♏v.
Syrupi zingiberis, ʒss.
Aquam ad ℥i.

22.—**Mistura Hydrargyri Perchloridi.**

Liquoris hydrargyri perchloridi, ʒss ad ʒi.
Aquam ad ℥i.

23.—**Mistura Potassii Iodidi.**

Potassii iodidi, gr. v. ad gr. xx.
Aquæ, ℥i.

24.—**Mistura Potassii Iodidi cum Ammoniâ.**

Potassii iodidi, gr. v. ad gr. xx.
Ammoniæ carbonatis, gr. iii.
Aquæ, ℥i.

25.—**Mistura Potassii Iodidi cum Ferro.**

Potassii iodidi, gr. v. ad gr. x.
Ferri et ammonii citratis, gr. v.
Aquæ, ℥i.

26.—**Mistura Strychninæ cum Acidi Phosphorici.**

Liquoris strychninæ hydrochloratis, ♏v.
Acidi phosphorici diluti, ♏xv.
Tincturæ Aurantii, ʒss.
Aquam ad ℥i.

27.—**Misturæ Quininæ Acida.**

Quininæ sulphatis, gr. i. ad gr. iii.
Acidi sulphurici diluti, ♏v.
Aquæ, ℥i.

28.—**Mistura Quininæ cum Ferro.**

Ferri et quininæ citratis, gr. v.
Aquæ, ℥i.

29.—**Pil. Quininæ cum Ferro.**

Quininæ sulph., gr. i.
Ferri tartrati, gr. i.
Morph. acet., gr. $\frac{1}{16}$ ad $\frac{1}{24}$.
Confect. rosarum, q.s.

For facial neuralgia. One to be taken every hour.

30. **Unguentum Flavum Dilutum.** (*Syn.*, **Pagenstecher's Ointment.**)

Hydrargyri oxidi flavi, gr. ss. ad gr. ii.
Vaselini, ʒi.

Useful in corneal ulceration, when there is not much photophobia.

31.—**Unguentum Flavum Dilutum cum Atropina.**

Atropinæ sulphatis, gr. $\frac{1}{4}$.
Hydrargyri oxidi flavi, gr. i.
Vaselini, ʒi.

As above. Sometimes relieves photophobia.

32.—**Unguentum Hydrargyri Nitratis Mitius.**

Unguentum hydrargyri nitratis (B.P.), ʒi.
Adipis preparati, ʒvii.

Useful in the treatment of blepharitis. Not to be confounded with the Ung. Hyd. Nit. Dilutum (B.P.), which is much stronger.

33.—**Unguentum Iodoformi.**

Iodoformi, gr. ii.
Vaselini, ʒi.

May be applied beneath the upper lid in purulent ophthalmia.

34.—**Unguentum Cocainæ.**

Cocainæ (alkaloid), gr. v.
Vaselini, ʒi.

35.—**Unguentum Flavum Dilutum cum Cocainæ.**

Cocainæ (alkaloid), gr. v.
Hydrargyri oxidi flavi, gr. v.
Vaselini, ʒi.

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